NEW PHYSICAL GEOGRAPHY

R. S. TARR


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NEW PHYSICAL GEOGRAPHY

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Frontispiece.

Fig. 1. — The Colorado Canyon.

NEW

PHYSICAL GEOGRAPHY

BY

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PREFACE.

NEARLY eight years ago the author published his Elementary Physical Geography, which was followed, two years later, by his First Book of Physical Geography, really a presentation, in briefer and more elementary form, of the matter contained in the earlier book. The growth of the science of physical geography, — which has been little short of marvelous, — the rapid advance in rank which the subject has won for itself in the schools, and the new ideas and new methods of presentation which have come to the author, have, for several years, made him desirous of undertaking a revision of one or both of his texts. When, however, this desire was given concrete form, and systematic attention was paid to the nature of the revision, it became evident that it would mean, not merely a revision, not even a mere rewriting, but a complete destruction of the old book and the construction of an entirely new book, different in plan, in scope, and, in many respects, in subject-matter. Then, for the first time, arose the idea that, since it would be a new book in fact, it would be better to issue it as such than as a new book under an old title. One important reason for reaching this decision was the fact that both the Elementary and First Book are in wide use. A field for them evidently exists, and it appears hardly wise to destroy absolutely that for which there is a demand. Twelve editions of the Elementary have been published and fifteen of the First Book.

The teaching of physical geography is still in its experi-

mental stage, and it is the opinion of many teachers that the ideal method of presentation has not yet been proposed, notwithstanding the several excellent texts which have appeared. The New Physical Geography is still another effort to solve the problem of how best to present the subject to beginning students. The author does not flatter himself that he has produced the ideal; his only hope is that he has done better in his third attempt than he did in the other two.

In the New Physical Geography, treatment of the lands has been placed before that of air and ocean because so many schools commence the study in the fall and take classes into the field. The chapters on atmosphere and ocean have been given less space than in the author's previous books; yet all topics of distinct importance are treated with sufficient fullness to make them clear. Certain subjects that are not universally deemed necessary parts of physical geography are treated in appendixes; it is the belief of the author that each of these should be studied.

Perhaps the most decided difference between the New Physical Geography and the author's other books lies in the introduction of a much fuller treatment of life in its relation to the land, air, and ocean, the human interest of each topic being emphasized. This has been done throughout the text and, at the end of the book, in a series of chapters devoted to that subject exclusively.

Especial pains has been taken to illustrate the book fully. It is believed that an illustration, properly selected, is of the very highest value, — the best substitute for the object itself. Every illustration in the book is introduced for use, and almost every one is referred to at least once in the text. Among these illustrations half tones of photographs predominate, for they alone, of all forms of illustration commonly in

use, present the whole truth. In order that they shall be distinct, the half tones are all printed on glossed paper; but to avoid giving the book undue weight, and to eliminate the trying effect of glossed paper on the eye, the text is printed on a light-weight, dull-finished paper and the half tones on inserted sheets. Besides half tones there are many diagrams, maps, and block drawings, the latter prepared by C. W. Furlong of Cornell University.

As aids to the study of the text, a brief Summary is given at the close of each section, and a Topical Outline and a set of Review Questions are placed at the end of each chapter. It is believed that the great majority of teachers will welcome these aids. No teacher will, of course, be content to follow the questions absolutely and without modification; the individuality of the teacher will appear here, as elsewhere. But these summaries, topics, and questions cover the essentials in the text; and their use as a basis for work, with such modifications and additions as may be deemed necessary, will be a far lighter task than the production of an entire series by the teacher. Thus, relieved of a form of drudgery, time will be available for the expenditure of energy in more profitable lines.

In most of the better schools physical geography is fast becoming a laboratory science, and this is the position it must eventually take wherever taught. In the absence of a laboratory manual, many teachers find it difficult to plan a laboratory course. That this is so is evident from the many letters that the author receives on the subject. With this in mind, a series of Suggestions is appended to nearly every chapter, and one appendix is devoted to maps and laboratory equipment, another to field work. From these suggestions any teacher will be able to select some for use. It is hoped that they may serve as an incentive to additional laboratory and field work.

A very large number of teachers have given the author the benefit of their experience in the form of suggestive criticism. To all of these teachers — making a list far too long to print here — the author is greatly indebted for their kindly interest. They have helped to shape the plan of the book. Among these, however, are several whose suggestions were of such marked value that their aid must be acknowledged individually: Frank Darling, Chicago Normal School; C. S. Jewell, Lake View High School, Chicago; E. C. Case, Milwaukee Normal School; L. O. Towne, Haverhill, Mass.; Emerson Rice, Hyde Park, Mass.; H. L. Rand, Dedham, Mass.; H. L. F. Morse, Troy, N.Y.; Miss Agnes Brown, Rockford, Ill.; and James A. Barr, Stockton, Cal. Special acknowledgment must also be made to Lawrence Martin of Cornell for valuable assistance and suggestion during the preparation of the book.

RALPH S. TARR.

ITHACA, N.Y., July 21, 1903.

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ACKNOWLEDGMENT OF ILLUSTRATIONS.

Aside from the illustrations acknowledged in the list below, and a few acknowledged beneath the pictures themselves, a number of photographs were obtained from a great variety of sources, American and foreign. Many of the photographs were taken by the author; many are from the collection in the department of Physical Geography at Cornell University. For photographs, especial acknowledgment is due Mr. J. O. Martin, formerly of Cornell University; William H. Rau, Philadelphia; F. J. Haynes, St. Paul; Detroit Photographic Co., Detroit; and S. R. Stoddard, Glens Falls, N.Y. The topographic maps are made from the United States Geological Survey topographic sheets; the weather maps and many of the diagrams of temperature, etc., are based upon maps and data obtained from United States Weather Bureau publications. Most of the relief maps are reproduced from models made by E. E. Howell, Washington; many of the drawings, especially the block drawings, are by C. W. Furlong, of Cornell University. The animal pictures and the map and picture of the races of man are by Matthews-Northrup Co., Buffalo. A number of illustrations were taken from earlier books by the author.

Of the remaining illustrations a few are made from copy whose source could not be ascertained. Illustrations taken from books, or based upon maps or diagrams in books, and a few photographs not purchased from dealers, are acknowledged in the following list: —

Abbe, C., Jr. (Maryland Weather Bureau), 122, 123; (Maryland Geological Survey), 463.

Agassiz, A. (Three Cruises of the Blake), 324, 325, 343.

Bartholomew (Physical Atlas, Meteorology), 407, 435.

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INTRODUCTORY.

MAN is vitally dependent upon air, water, and earth. The air supplies oxygen for breathing and for fire; it supplies carbon dioxide to plants; it brings vapor for rain; and its presence and movements profoundly affect climate.

The ocean is the source of vapor; it furnishes many kinds of food fish; it is the highway of an ever increasing commerce; and it influences the climate of every land.

The lands furnish a home for man; they are mantled with a soil in which the food plants grow; and from the rocks are obtained mineral fuels, building stones, and metals. Both plant and animal life are greatly influenced by the forms of the land and the distribution of land and water.

The sun is also of vital importance, for its heat and light make life on the globe possible. The heat sets the air in motion, forming winds which bring rain, modify climates, and start waves and currents in the ocean.

The movements of the earth — rotation and revolution — are also important. Rotation brings day and night, which influence the habits of men, animals, and plants. Revolution causes seasons, which have a still greater effect on life.

Plants, animals, and mankind have adapted themselves in a wonderful manner to the soil, climate, and other features of their surroundings. Most animals and plants live either in the water or on the land; but some have adopted the air as their home, while others have taken to life underground, though always near the surface.

Air and water are ever changing; the lands are also changing, though more slowly; and plants and animals are varying in their relation to air, ocean, and land. These changes have a profound effect on man, and it is therefore important to study about them.

Such a study is known as **Physical Geography, which may be defined as the study of the physical features of the earth and their influence on man.**

NEW PHYSICAL GEOGRAPHY.

CHAPTER I.

THE EARTH AS A PLANET.

1. Shape of the Earth. — When we look at the full moon we see clearly that it is a sphere in the heavens (Fig. 2). If we could stand on the moon and look at the earth, we would see that it, too, is a sphere. But the earth is a much larger sphere than the moon (Fig. 3).

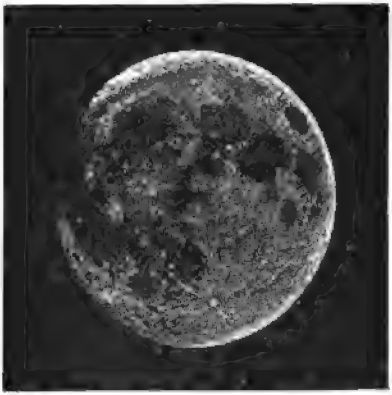

FIG. 2. — The moon.

Over two thousand years ago it was known that the earth was a sphere; but this was later forgotten, and for a long time the earth was believed to be flat. Before the time of Columbus, navigators imagined all sorts of terrors at the edge of a flat earth; and Columbus had difficulty in finding sailors who were willing to face these imaginary terrors. Columbus's voyage helped to bring into prominence the old proofs that the earth is a sphere.

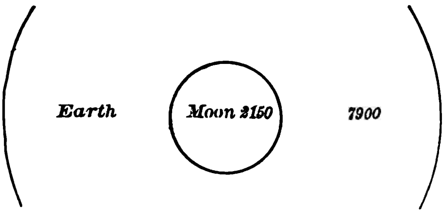

FIG. 3. — Relative size of earth and moon. The figures are the diameters in miles.

No matter where one may stand on the seashore, or on a vessel in the open ocean, he may find proof that the earth's surface is curved (Fig. 4). The sails and smoke of distant ships are seen while the hulls are hidden behind the curvature of the earth (Fig. 6). As the ship comes nearer, more and more of it is seen. This does not prove that the earth is a sphere, for other curved bodies, such as an egg-shaped one, would produce the same effect.

Fig. 4.—The curved ocean surface.

That the earth is spherical is now proved, and its size and exact form have been measured by scientists. Travelers have gone around it in various directions, and it is known how far one must travel to return to the starting point. Among the proofs that the earth is a sphere, and one known to the ancient Greeks, is that furnished by eclipses of the moon. Such an eclipse is caused by the earth's shadow thrown on the moon when the earth comes between the sun and moon. This shadow is always bounded by part of a circle (Fig. 5). If the earth were not a sphere this could not be so, for in some positions its outline would be certain to show the true form.

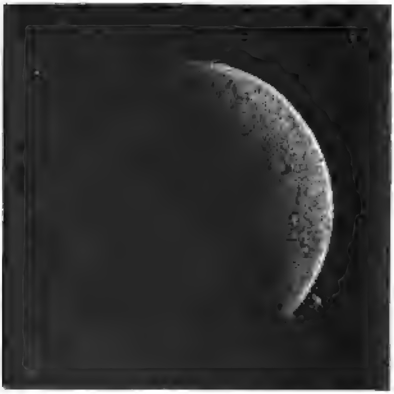

Fig. 5.—Curved shadow of the earth during an eclipse of the moon.

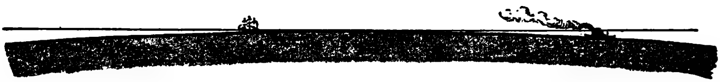

Fig. 6.—To show why part of a distant ship is hidden. The straight line is the line along which a man on the deck of the sailing vessel would look.

The earth is not an exact sphere, for the diameter at the equator is 7926 miles, and at the poles 7899. This difference in the two diameters is due to a slight flattening at the poles. Such a slightly flattened sphere is called an *oblate spheroid*. Compared to the earth as a whole this flattening is so slight that it cannot be shown on an ordinary globe.

Summary. — *The earth is a slightly flattened sphere, or oblate spheroid. Its curved surface can be seen on the ocean; eclipses of the moon prove that it is a sphere; its size and shape have been measured; and the distance around it in all directions is known.*

2. Other Spheres. — The earth is only one of a great number of spheres in space. The nearest of these is the moon, whose average distance is about 240,000 miles. All the stars are also spheres, far larger than the moon, and billions of miles away. At the rate of an express train it would take tens of thousands of years to reach the nearest star. These stars are all fiery hot; but the moon is a cold mass of rock.

The huge sun, another sphere, is a star with a diameter of 860,000 miles (Fig. 7). Its average distance from the earth is 92,750,000 miles, and yet it is so hot that heat and light from it cross that distance, making life on the earth possible.

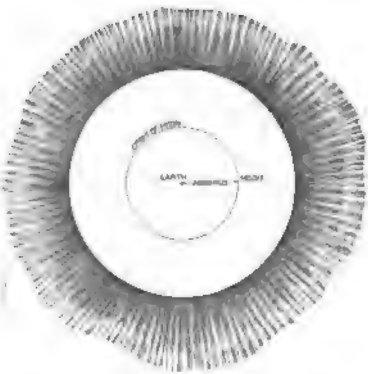

Fig. 7. — To show the great size of the sun. The earth, moon, and orbit of the moon could all be placed inside the sun, as shown.

The sun is the center of a family of spheres which form the *solar system*. In this system there are eight large spheres called *planets*, of which the earth is one. The sun and stars shine by their own light; but the planets merely reflect sunlight, as the moon does. The bright evening and

morning "stars" are planets, like the earth. From one of them the earth would be seen to have the same steady, bright light that they show to us.

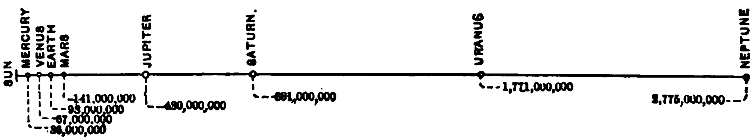

Fig. 8.—The relative distance from the sun to the different planets. The figures are distances in miles.

Some of the planets are far more distant than the sun (Fig. 8), Neptune, the most distant of all, being over 2,700,000,000 miles. How distant that is may perhaps be understood by the following illustration. If an express train could have started toward Neptune in the time of Christ, and have traveled steadily onward day and night at the rate of sixty miles an hour, it would not yet be halfway there.

Not only are the planets far away, but some of them are very large (Figs. 9, 10). Jupiter, the largest, is 86,000 miles in diameter. In the space between Mars and Jupiter there are also a number of very small spheres, called *asteroids*. The largest is about 500 miles in diameter.

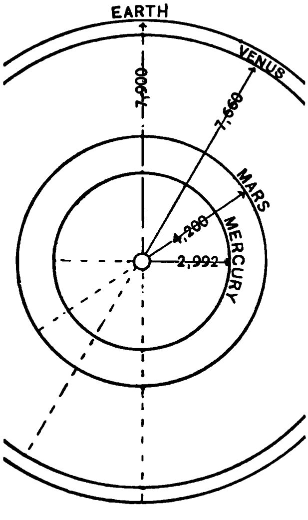

Fig. 9.—To show the relative size of the four smaller planets. The figures are diameters in miles.

Summary.—*Other spheres besides the earth are the stars, sun, moon, planets, and asteroids. The moon and planets are cold, and shine by reflected light; the stars and sun are fiery hot. In the solar system, which includes the sun, moon, planets, and asteroids, the largest sphere is the sun, the largest planet Jupiter, and the most distant planet Neptune.*

3. Movements of the Spheres. — Little is known about the motions of the distant stars. But all the planets whose movements are known have been found to turn, or *rotate*, on an axis. The earth takes one day for *rotation*; the sun over 25 days; Jupiter 9 hours, 55 minutes; the moon $27\frac{1}{3}$ days.

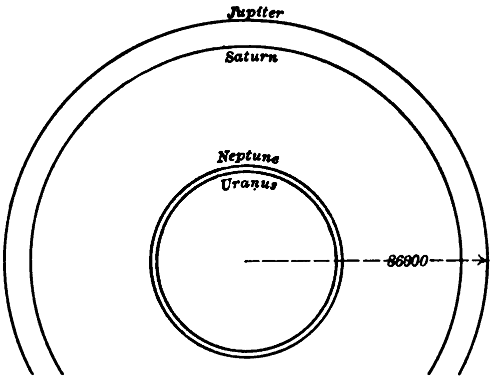

FIG. 10. — To show the relative size of the four larger planets.

All members of the solar system also travel, or *revolve*, around the sun. This *revolution*[1] is along a nearly circular path, or *orbit*. The orbit is not an exact circle, but an *ellipse* (Fig. 11), and the sun, instead of being at the center, is a little to one side, at one of the *foci* of the ellipse. This causes the earth to be nearer the sun at one season (over 91,000,000 miles) than in the opposite (over 94,000,000 miles), when it reaches the other end of the ellipse. The earth requires a little over 365 days, or one year, to make a complete revolution around the sun.

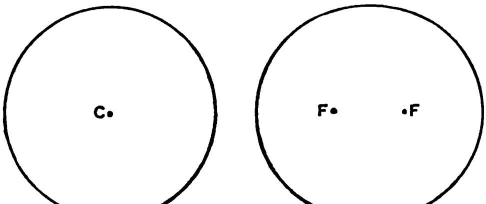

FIG. 11. — A circle (on left) and ellipse (on right). Find the center of the circle (C) and the foci of the ellipse (FF).

[1] For fuller treatment of revolution, see Appendix A.

Mercury, the smallest and nearest of the planets (Figs. 8, 9), requires only 88 days for a single revolution. What is the time required by the other planets (Fig. 12)?

Several of the planets have moons. The word *satellite*, meaning follower, is given to these smaller spheres because they follow their planets in their revolution around the sun. The earth has one moon; no moons have been discovered for Mercury or Venus; but Saturn has eight. It is believed that each satellite rotates on an axis and revolves in an ellipse around its planet. The moon makes one revolution around the earth in about 27⅓ days.

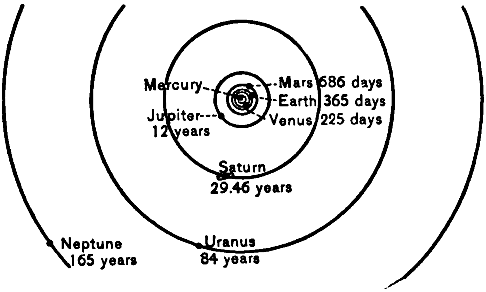

FIG. 12. — Time of revolution of the planets.

Summary. — *So far as known, all the planets rotate on axes, and all revolve around the sun in elliptical orbits. The periods of rotation and revolution differ. Satellites accompany several of the planets.*

4. Rotation of the Earth. — Many uninformed people believe that the sun rises, passes through the heavens, and sets in the west. Our own ancestors, centuries ago, held the same belief. We still use their terms, *sunrise* and *sunset*, though we well know that it is the turning of the earth on its axis that makes the sun appear to rise and set. In looking from the window of a train it sometimes seems as if objects were passing by, while it is really you yourself that is moving. In the same way, as the earth turns with us toward the east, the sun seems to travel in the opposite direction.

The rising and setting of the moon, and the apparent movements of the stars at night, are also due to the earth's rotation.

Find the North Star by following the pointers on the outer side of the Great Dipper (Fig. 13). Notice that it does not move at night, but that the Dipper and other stars seem to swing around it. The farther a star is from the North Star the greater the circle through which it swings, those far away rising in the east and setting in the west. It used to be thought that the sky was a great dome with stars set in it, a few miles from the earth, and that it slowly swung around the earth. We now know that the earth's axis points toward the North Star and that, as the earth turns, it causes the stars to appear to swing round the North Star.

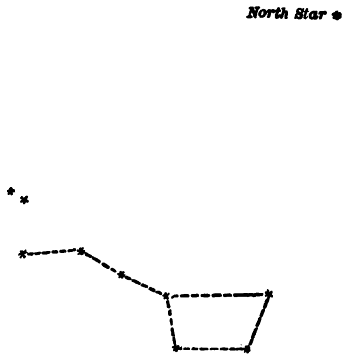

FIG. 13. — The Great Dipper and North Star.

Summary. — *It was formerly thought that the sun, moon, and stars moved; we now know that these apparent movements are caused by the earth's rotation. The axis of the earth points toward the North Star; therefore the other stars seem to circle round it.*

5. Effects of Revolution and Rotation. — Rotation of the earth has given the basis for our time. We reckon a day as the period required for one rotation (a little over 23 hours and 56 minutes). The day is divided into hours, each hour being the time required for the sun's rays to advance 15° over the curved surface of the rotating earth. By rotation, also, the day is divided into a period of light and one of darkness. Name some habits of plants, animals, and men that are determined by this effect of rotation.

Revolution of the earth is also a matter of the highest importance. By it another standard of time, the year, is fixed. Revolution also causes an apparent movement of the sun, by which it rises and sets farther north or south at different times. These changes in the sun's position,

which cause the seasons, have determined some of man's most characteristic habits. Name some ways in which revolution affects you,—your home, clothes, foods, and games. Recall from your study of geography how revolution affects the habits of the Eskimos.

Summary. — *Rotation determines the length of our day, causes day and night, and influences our habits. Revolution gives us our year, our seasons, and also profoundly affects our habits.*

6. Gravity and Gravitation. — The earth exerts on all bodies upon it an attraction which we call *gravity*. By gravity men are held to the surface of the earth; a stone thrown into the air is drawn back to the earth; the air is prevented from flying away into space; and the oceans are held in place. It gives to the ocean a curved surface, because each particle of water is attracted toward the center of the sphere. Each part of this curved surface, or *sea level*, is at right angles to a line leading toward the earth's center.

Bodies in space also exert an attraction on other spheres. For example, the moon exerts an attraction upon the earth, and the earth upon the moon; but the earth, being larger, has the stronger effect. This attraction of bodies in space is called the *attraction of gravitation*.

The attraction of other spheres pulls more strongly on the larger equatorial part of the earth than on the flattened polar region. This causes the axis of the earth to be inclined at an angle of $23\frac{1}{2}°$. If the flattening at the poles were greater, the axis would be inclined still more.

Gravitation is the bond that holds the earth and other planets to the orbits along which they travel about the sun. If it could be possible for the sun to lose its attraction of gravitation, the earth would fly off into space, as a stone whirled by a string flies away if the string breaks. Gravitation also holds the moon so firmly that it swings around the earth with such regularity that its position a thousand years from now can be accurately foretold.

Held by gravitation, the earth is able to travel along its orbit of 600,000,000 miles each year at a rate of over 1000 miles a minute. At the same time, it is whirling on its axis so rapidly that a person on the equator is moving at the rate of 17 miles a minute. We are not aware of these rapid movements, because the land, water, and air go with us. Even when traveling on a noisy railway train, we sometimes forget that we are moving. But the earth moves without jar or noise, and there are no near-by objects for us to swiftly pass; therefore, for many generations men did not even suspect that they were moving at all.

FIG. 14. — Craters on the moon, seeming to indicate former volcanic eruptions due to a heated condition of the interior.

Summary. — *Gravity is the attraction that holds objects to the earth; it causes the curved surface called sea level. Gravitation is the attraction exerted by bodies in space; it causes the inclination of the earth's axis; and it holds the spheres to their orbits.*

7. Heat in the Solar System. — The sun is the only member of the solar system that is hot enough to glow; but in past ages the other members have apparently also been hot. Jupiter appears still to be so warm at the surface that the water rises in clouds of steam. The earth is cold

at the surface, but hot within (p. 17); the small moon, though now cold, was apparently once hot within.

The heat of the sun is so great that even mineral substances exist in the form of gases. This white hot sun is slowly cooling by radiating its heat off into space; but a few small points, of which the earth is one (Fig. 15), intercept a minute portion of these rays, on which animal and plant life depend.

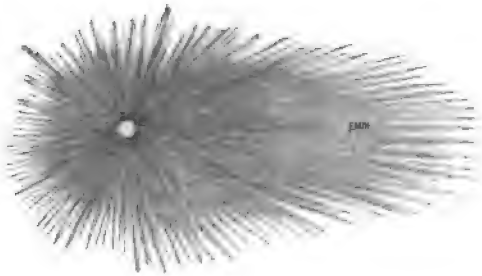

Fig. 15. — To illustrate the very small proportion of all the rays passing out from the sun that reach the earth.

With great speed these rays cross the 93,000,000 miles that separate us from the sun. They reach the earth in about 8 minutes, while, at the rate of a fast express train, 175 years would be required. The distant planet Neptune doubtless receives too little heat for life; Mercury is so near that it perhaps receives too much; but the earth is so favorably situated that it receives neither too much nor too little. As the sun cools down to a red heat, in some far-distant future age, life on the earth will no longer be possible.

Summary. — *The members of the solar system show signs of heat, either past or present. Heat, radiated from the white hot sun, passes rapidly across space; and some of it, reaching the earth, makes life possible.*

Topical Outline, Questions, and Suggestions.

Topical Outline. — 1. **Shape of Earth.** — Former belief; proofs of roundness; exact shape; length of diameters.

2. **Other Spheres.** — The moon; stars; sun; solar system; relative size of planets; relative distance; asteroids.

3. **Movements of the Spheres.** — (*a*) Rotation: time required. (*b*) Revo-

lution: nature of path; effect on distance from sun to earth; time required. (*c*) Satellites: meaning of name; number; movements.

4. **Rotation of the Earth.** — Apparent movement of sun; former belief; real explanation; movements of stars; explanation.

5. **Effects of Rotation and Revolution.** — (*a*) Rotation: effect on divisions of time; on day and night; on habits of man. (*b*) Revolution: effect on division of time; on seasons; on habits of man.

6. **Gravity and Gravitation.** — (*a*) Gravity: nature; effects; nature of sea level. (*b*) Gravitation: nature; inclination of earth's axis; movements of moon and planets. (*c*) Rapid movements of earth.

7. **Heat in the Solar System.** — (*a*) Evidence of heat in the solar system. (*b*) Sun's heat: condition of sun; rate of passage of rays; proportion received by earth; other planets; effect of future cooling of sun.

QUESTIONS. — Section 1. What was formerly believed concerning the shape of the earth? What proof is there that the earth is spherical? What is its exact shape? Give its two diameters.

2. What other kinds of spheres are there? How do planets and stars differ? What is the solar system? What are asteroids? Give the distance from the sun to each of the planets (Fig. 8). Name the planets in the order of their size (Figs. 9 and 10).

3. What important movements have the planets? State the difference in time of rotation. Of revolution. What is the distance from earth to sun at opposite seasons? Why this difference? Give some facts about satellites.

4. What was formerly thought regarding the daily movement of the sun? What is now known to be the cause of it? Describe the movement of the stars, and explain them.

5. What are the important effects of rotation? Of revolution?

6. What is gravity? Give examples of its effects. What is the attraction of gravitation? What effect has this upon the earth's axis? Upon revolution? Why are the earth's movements not more noticeable?

7. What is the evidence of heat in the members of the solar system? What change is going on in the sun? What effect has that on the earth? Why is there probably no life on Neptune or Mercury? At what rate does sunlight travel?

SUGGESTIONS. — *These suggestions are made rather freely, though it is not expected that any school will find it feasible to carry out all, or even a majority. From among them, however, every teacher will find it possible to select some.* (1) Carefully examine the moon and note its roundness. If possible, look for the craters through a telescope or spyglass. (2) If an eclipse of the moon comes during the year, observe it and note the circular outline of the earth's shadow. (3) With a lamp, throw on the wall the shadow

of a ball in various positions. Do the same with a cylinder; with a square. Which always shows one kind of outline? (4) A period devoted to the meaning of scale may be combined with a study of the size and distance of the members of the solar system. This can be done with profit by cutting disks out of brown paper to represent the planets (say on a scale of one inch for 5000 miles); and marking off distances in the school yard (say on a scale of one inch for 200,000 miles) to represent distances. (5) Take a string five feet long with a loop in the end. Put the loop over a nail driven in the floor. With a piece of chalk at the other end of the string draw a circle. Now drive another nail two inches from the first. Take a string ten feet long and tie the ends. Put it over the two nails, and with chalk held in the loop draw a figure as near a circle as you can. It will not be a circle, but an ellipse. If you put the two nails (the foci) farther apart, say six inches, the ellipse will be still less like a circle. (6) Rotate a globe or apple in front of a light to understand the cause of day and night. (7) Observe the stars of the Great Dipper and the North Star at 8, 9, and 10 o'clock. What changes do you notice? (8) Compare the movements of a planet in the heavens, say the evening "star," with that of a neighboring star. Why the difference? (9) With a telescope look for the moons of Jupiter and the rings of Saturn. (10) What are shooting stars and comets? (11) In some astronomy, read about the sun and the planets. (12) Find out what Aristotle, Magellan, and Galileo learned about the earth.

Reference Books. — *References to a few selected books are placed at the end of each chapter. Other reference books and magazines are listed in Appendix L.* NEWCOMB, *Elements of Astronomy*, American Book Co., New York, 1900, \$1.00; YOUNG, *Manual of Astronomy*, Ginn & Co., Boston, 1902, \$2.45; TODD, *New Astronomy*, American Book Co., New York, 1897, \$1.30; LOCKYER, *The Chemistry of the Sun*, Macmillan Co., New York, 1887, \$4.50.

CHAPTER II.

GENERAL FEATURES OF THE EARTH.[1]

THERE are three quite different parts of the earth: (1) the solid earth; (2) the liquid ocean which partially covers the solid earth; and (3) the gaseous envelope, or atmosphere.

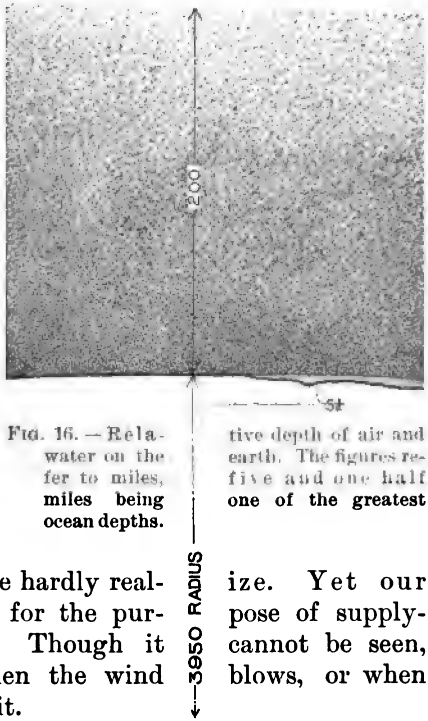

FIG. 16. — Relative depth of air and water on the earth. The figures refer to miles, five and one half miles being one of the greatest ocean depths.

8. The Atmosphere.[2] — There is some air at a height of 200 or 300 miles from the earth; but most of it is within a few miles of the surface. The air is a mixture of transparent gases, mainly oxygen and nitrogen, whose presence on every hand we hardly realize. Yet our every breath draws it in for the purpose of supplying life-giving oxygen. Though it cannot be seen, we feel its presence when the wind blows, or when moving rapidly through it.

There are many ways in which the air is of high importance. All plants and animals depend upon its gases for life. Its oxygen

[1] For latitude and longitude, see Appendix B; for maps, see Appendix I.
[2] See also Chapter XII.

causes fire to burn, and, by a slow combustion, causes decay of animal and plant tissues. It diffuses light and heat from the sun, and transmits the sound waves upon which hearing depends. Winds, which bear vapor and warm and cold air from place to place, are a result of its movement. For many centuries the wind has been used for driving ships through the water and for turning windmills on the land.

The surface of the earth itself is profoundly modified by the influence of the air. Winds move loose fragments about and wear the rocks away, especially in desert regions. Rains, made possible by vapor in the air, give rise to streams, which carve channels in the land and bear rock fragments to the sea. Waves, which winds form in the ocean, batter at the rocky seacoast. Even quiet air, by the action of its water vapor and oxygen, is causing the solid rock to slowly decay and crumble. This forms the soil upon which so many plants depend for food.

Summary. — *The air, composed chiefly of oxygen and nitrogen, extends* 200 *or* 300 *miles above the earth, but is mainly near the surface. Breathing, fire, decay, diffusion of light and heat, hearing, winds, rain, waves, and many changes of the land, including the formation of soil, are dependent on the atmosphere.*

9. The Oceans.[1]—If the earth were a perfect sphere, it would be entirely covered by water to a depth of several thousand feet; but the surface is so irregular that the ocean is not able to completely cover it, as the air does. It has been drawn by gravity into the depressions and rises high enough to cover only the continent margins (Fig. 316).

Nearly three fourths of the solid earth is hidden from view by this water mantle, the area of the oceans being about 145,000,000 square miles, of the lands about 52,000,000 square miles. Near their contact with the continents the oceans are shallow; but far from land the water is deep. One may sail, with no land in sight, for thousands of miles in water whose average depth is 10,000 to 15,000 feet. In

[1] See also Chapter X.

its deepest parts the ocean has a depth of over five and a half miles.

This vast expanse of water is of great importance in many ways. It is the seat of abundant life, many forms of which are of such value that ships are sent out to secure them. Cod, halibut, haddock, bluefish, salmon, shad, lobster, oyster, clam, seal, whale, sponge, pearl oyster, and precious coral are among the ocean animals of importance to man.

For a long time the ocean was an almost impassable barrier to the spread of man; but as men learned to navigate and to build strong ships, it became a highway instead of a barrier. To-day the Atlantic is crossed with speed and comfort in five or six days; less than a century ago this journey required weeks and was one of peril. To-day communication between America and Europe is easier than between Rome and Athens at the time of the Roman Empire. Ships now cross the oceans in all directions, carrying merchandise and passengers to every quarter of the globe. The harbors from which these ships go forth have become the seats of great cities, prospering by their commerce and by the industries to which it gives rise. By means of the ocean highway, too, civilization has rapidly spread to all quarters of the globe.

It is the ocean that supplies the vapor for rain, upon which all land animals and plants depend. The ocean also profoundly influences the temperature of neighboring lands, moderating the heat of summer and the cold of winter. Therefore, lands reached by ocean winds, like the northwestern coast of United States and Europe, have far less extreme climates than lands in the same latitude, like central and eastern United States, where ocean winds are less common.

Summary. — *The ocean occupies depressions on the earth's surface, covering three fourths of the globe to an average depth of* 10,000 *to* 15,000 *feet. The ocean is of importance as a source of food-fishes, and other valuable animals; as the seat of extensive navigation; as the source of vapor; and in modifying climate.*

10. The Solid Earth. — Near the continents the sea floor is covered with sediment washed from the land by rain, rivers, and waves. Farther out, it is mantled with the remains of animals that, on dying, have settled from the water above. Almost everywhere on the dry land there is a layer of loose rock fragments, the surface part of which is called *soil*. Thus nearly the entire earth is covered by loose materials.

In some places the soil has been brought by glaciers, in others by rivers; but most of it has been formed by the decay and crumbling of the rocks. Were it not for this soil most of the plants, which are of such use in supplying materials for food, clothing, and shelter, could not grow. The soil offers a chance for the roots to penetrate, seeking water and plant food, and also holding the plants upright.

Fig. 17. — Rock beneath the soil.

Wherever the soil mantle is penetrated to great enough depth, solid rock is found beneath it (Fig. 17). Sometimes the rock is several hundred feet beneath the surface; but it is usually found at a depth of a few feet or a score or two of feet. In places, especially among mountains or on other steep slopes, there is no soil-cover at all. As the rock decays in such situations, the fragments fall away so quickly that soil cannot accumulate.

The rock that is everywhere found beneath the soil varies greatly from place to place, often consisting of materials which are of great use to man. In some places it is sand-

stone or granite, useful for building purposes; in other places it is limestone, valuable for building, for making lime, or for use in blast furnaces. In various parts of the world, layers of coal are found bedded with the rocks; and there are deposits of iron ore, salt, and other substances; also veins of lead, zinc, silver, gold, and other metals.

Summary. —*The solid earth, like the air and ocean, is of great importance to man. It furnishes him with a home; it is almost everywhere covered with a soil mantle, in which food and other plants grow; everywhere beneath the soil mantle is found solid rock, from which many valuable mineral substances are obtained.*

FIG. 18. — To show the relative thickness of the air and solid earth.

11. The Earth's Interior. — From river valleys, tunnels, quarries, mines, and well borings many facts have been learned about the outer part of the solid earth. But this knowledge tells little about the great interior. However, astronomers have shown that, while the outer part of the earth is from 2 to 3 times as heavy as water, the interior is $5\frac{1}{2}$ times as heavy. It is perhaps made of metal.

Several facts indicate that the interior is highly heated: there are hot springs; volcanoes erupt melted rock; and mines show an increase in temperature of 1° for every 50

or 60 feet of descent. If this increase continues, the melting point of rocks must be reached at no great depth.

It was formerly believed that beneath a thin outer crust the interior was molten; but it is now considered certain that, though very hot, the interior is solid. We still use the term *earth's crust*, however, for the cold outer portion of the earth. There are a number of reasons for the belief that the interior is solid: (1) if it were liquid there would be tides in it; (2) the behavior of the earth toward other spheres is that of a solid body; (3) earthquake shocks in Japan have been measured by delicate instruments in England, and the time of passage indicates a solid interior.

It is a well-known fact that greater heat is required to melt a substance under pressure than without pressure. It is believed, therefore, that the interior of the earth is prevented from melting by the tremendous weight, or pressure, of the rocks that rest upon it. At a depth of six miles the pressure is great enough to crush rocks; and, therefore, deep in the earth, below this upper portion, or *zone of fracture*, cavities cannot exist.

The interior heat is one of the arguments in favor of the belief that the earth was once a still hotter body (p. 9), probably part of a *nebula*, from which the sun, earth, moon, and the other members of the solar system have descended. The earth is still losing heat; but it is so large that many ages more will be required to make it completely cold, like the smaller moon.

Summary. — *Several facts indicate that the interior of the earth is highly heated, and it was formerly thought to be molten; but, for a number of reasons, it is now believed to be solid, though hot, being prevented from melting by the pressure upon it.*

12. Air, Water, and Rock. — At ordinary temperatures the air is a mixture of gases; but with great cold and pressure these gases may be changed to a liquid and even to a solid state. Water, ordinarily a liquid, changes at 32° to a solid,

and at 212° to a gas; in fact, some water-vapor gas rises from water at ordinary temperatures. Rock, as we know it, is a solid; but volcanoes show that under higher temperatures it becomes a liquid; and in the very hot sun, some of the rock elements are so hot that they are in the state of gases. From this it is seen that *the terms gas, liquid, and solid apply merely to a state of matter.* When the conditions change, either one of these states of matter may be altered to one of the other states.

The three earth materials — air, water, and rock — have been spoken of as if they were quite separate; but really they are closely related and mingled. There is not much rock material in the atmosphere, though volcanic dust is often borne long distances in it; and the haziness of the air is partly due to dust blown up from the ground. Water vapor is mixed with all air, even that of the driest deserts.

Water also pervades the earth's crust, entering even the densest rocks. Wells reach it and supply drinking water; it slowly oozes from the ground in springs; miners find it far below the surface; and volcanic eruptions bring vast quantities of it to the surface. In cold climates it is frozen, changing the soil to a solid, rocklike mass. In northern Siberia the ground is permanently frozen to a depth of several hundred feet. That air also enters the ground is proved by the fact that many plants die for lack of it when their roots are submerged.

Air is also mixed with water. If a fish is placed in water from which the air has been expelled, it will die because there is no oxygen for it to breathe. All water, on the land or in the sea, bears mineral substances in solution; and rock fragments mingled in suspension are also present in water.

Summary. — *Air (gas), water (liquid), and rock (solid) may each be changed to one of the other states of matter. They are mingled: there is earth material and water vapor in the air; air and water in the earth; and air and rock material in the water.*

13. Irregularities of the Earth's Crust. — While the earth is a huge sphere flattened at the poles, its outline is far from

regular. Its surface is roughened by a series of continent elevations, between which are broad depressions, occupied by the oceans. The ocean depressions average 10,000 to 15,000 feet in depth; but the average height of the lands above sea level is only 2000 to 3000 feet. Fully three fourths of the ocean bottoms are broad expanses of plain; and much more than half the land is either plain or plateau (Figs. 19, 21).

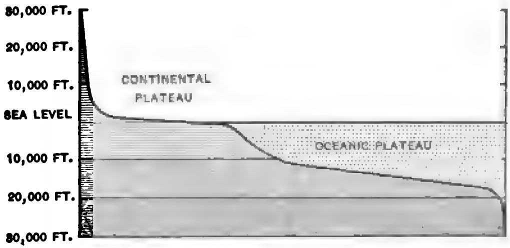

Fig. 19. — To show the proportion of continents and ocean basins between different levels.

Mountain chains and volcanoes rise high above the general level of both sea bottom and land. The Hawaiian Islands are volcanic cones on a submarine mountain fold fully 1500 miles in length; and the Japanese Islands, Philippines, and West Indies are also mountain chains rising from the sea floor.

It is among the mountain chains of the land that the greatest elevations on the globe are found. In the Andes there are peaks that are over 40,000 feet above the sea bottom 75 miles to the west. The highest mountain in the world, Mount Everest, is about 5½ miles high; and the greatest ocean depth is about the same distance beneath the sea. Eleven miles is a great height as we look at it; but it is a very small amount compared to 7900 miles, the diameter of the earth.

These irregularities of the earth's surface are generally believed to result from the heated condition of the interior (p. 9). As the earth cools and shrinks, its crust wrinkles, causing some parts to rise, others to settle (p. 35). Such changes of level are even now in progress (p. 36), and there are many proofs that they have caused great change in the past. One of the most important facts in physical geography is that the earth's

crust is in slow movement; for by reason of it, the outlines of the lands and oceans are ever varying.

Summary. — *The earth's surface has been roughened by the effects of shrinking of the heated interior. This has caused continent elevations and ocean depressions, and, on both of these, mountain chains and volcanoes. The average depth of the ocean is about five times the average height of the land; but the loftiest mountains are about as high as the greatest ocean depths, making a total difference in level of about eleven miles.*

14. Conflict of Erosion and Elevation. — Wherever land is exposed to the air, it is being attacked and slowly worn away. The weather causes the rocks to slowly crumble (p. 38); rivers carve valleys and carry the rock fragments off toward the sea (p. 52); glaciers scour the land over which they pass (p. 153); waves batter the shore, cutting cliffs, building beaches, and supplying rock fragments for removal by the currents (p. 210). The result of the work of these *agencies of erosion* is that the land surface is made very irregular.

The sea floor, on the other hand, is made more regular. Beyond the reach of the waves there is practically no erosion; but the deposit of rock fragments from the land is leveling the sea bottom.

Thus, on the one hand, movements of the crust are raising the land; on the other, the agencies of erosion are cutting into it and removing its fragments toward the sea. There is an opposition, or conflict, of two sets of forces, one set tending to raise, the other to lower the surface of the land. So far the forces of elevation have been most powerful; but the agencies of erosion have deeply sculptured the lands and have helped to level the sea floor.

This conflict has been in progress for many ages, and the present land surface, about which we are to study, is the result of it. The valleys, which our railways and canals follow; the mountains, which act as barriers to winds, and to the spread of plants, animals, and men; the smooth

coastal plains; the interior plateaus; the harbors in which our shipping gathers; the sites of our leading cities; and many other land features are a result of the conflict between the forces of elevation and the agencies of erosion.

Summary. — *Agencies of erosion — weather, rivers, glaciers, waves, etc. — are cutting into the land and strewing the waste over the sea floor. On the other hand, forces of elevation are raising the land. This causes a conflict, in which the forces of elevation have so far been most potent. The present land surface, which so greatly influences man, is the result of this conflict.*

15. The Continents — (A) *Characteristics.* — A continent is a large upraised portion of the earth's crust nearly or quite surrounded by ocean. Usually the continent margin is submerged beneath the sea (Fig. 316), sometimes, as off eastern North America, for a distance of 50 to 100 miles from the coast. At its outer edge it is faced by a steep slope, called the *continental slope* (Fig. 116), which descends quickly to the deep sea bottom. Although the average elevation of the continents is but 2000 to 3000 feet above sea level, when measured from the base of the continental slope their average height is 10,000 to 15,000 feet. Some portions, for example the Dead Sea, are below sea level.

Continents consist of mountain ranges with connecting plains and plateaus (Figs. 20, 21). They are crossed by rivers, occupying valleys, which drain the land; but nearly one fourth of the land has no drainage to the sea. In these cases the water runs into *interior basins*, or basins without outlet.

The outline of a continent seems to be determined by its mountain ranges; indeed, mountains have been called the skeletons of continents. From this standpoint the plains and plateaus may be called its tissues. In fact, the plains and plateaus have been built of rock fragments worn from the mountain skeleton.

To illustrate, off eastern Asia, from the Kurile Islands to the Philippines (Fig. 26), there is a mountain chain now rising. A large part of the rock waste worn from these mountains, and from

FIG. 20. — The main mountain axes of North America.

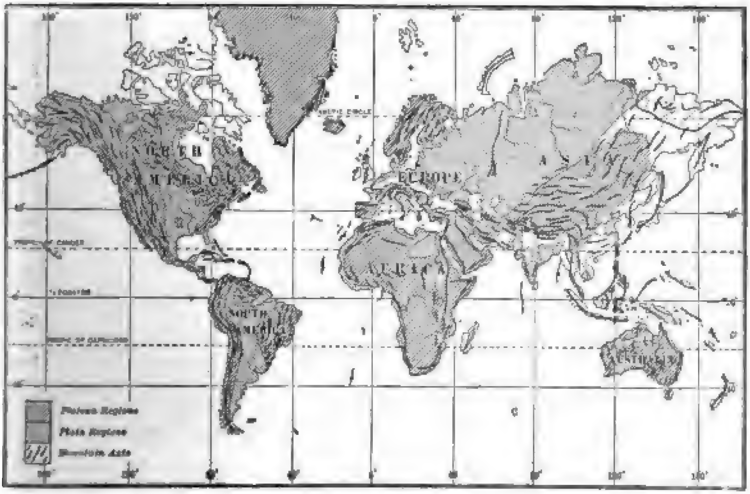

FIG. 21. — Diagram to show the general distribution of mountains, plains, and plateaus of the world.

FIG. 22. — Relief map of North America.

the mainland, is being deposited in the sea that separates the islands from the mainland. These deposits may in time fill the inclosed sea, and a slight uplift of the land may raise the smooth sea bottom plain, forming dry land, and thus joining the mountain islands to the Chinese coast. It is by similar changes that continents have been made.

Summary. — *Continents are uplifted blocks of earth's crust whose real margin is beneath sea level. They consist of plains, plateaus, and mountains, partly drained into interior basins. They owe their outline to mountain skeletons, connected by plains and plateaus, that have been built of rock fragments worn from the mountains.*

(B) *North America.* — In North America (Fig. 22) there are two great systems of mountains: (1) the Appalachian system, which extends southwestward from Labrador to Alabama; and (2) the great western system, or the *western Cordilleras*, which extends southeastward from Alaska to Central America (Fig. 20). A third system of low and very ancient mountains occupies the region from Labrador westward. The vast plateaus and plains that connect these mountains are largely made of rock fragments swept from the mountains in past ages. Fossil remains of marine animals prove that the rock strata were deposited in a sea, and were later raised by the forces of elevation to form dry land.

Its triangular mountain skeleton has given to North America its form. The continent is broad in the north and tapering in the south, because the mountains are spread farther apart in the north. Mountains have also caused some of the larger irregularities of the continent. For example, the Alaska and Labrador peninsulas are the northern extension of the western and eastern mountains (Fig. 22). Lower California is a southern extension of the Coast Ranges; and the Gulf of California is a depression not yet filled with the waste that is being washed from the bounding mountains. The peninsulas and islands which partly inclose the Gulf of Mexico and Caribbean Sea are also portions of mountain systems.

Sinking of the land, which allows the sea to enter the valleys, is another cause for irregularities in the outline of a continent. Such a sinking in northeastern America has submerged land valleys, forming Hudson Bay, the Bay of St. Lawrence, the Bay of Fundy, Long Island Sound, New York Harbor, Delaware Bay, Chesapeake Bay, and many thousands of smaller bays, estuaries, and harbors. Where the sea has risen so as to completely surround areas of higher land, islands have been formed, such as Long Island, Newfoundland, and the thousands of others along the northeastern and northwestern coasts of America.

Summary. — *North America owes its triangular shape to its mountain areas, spread apart in the north. The connecting plains and plateaus are made of rock waste derived from these mountain skeletons. The principal irregularities — peninsulas, bays, and islands — are due to two causes:* (1) *mountains;* (2) *sinking of the land.*

(C) *South America.* — South America resembles North America in its triangular form (Fig. 23). This outline is due to the great mountain backbone of the Andes in the west, and the less prominent mountain systems in the north and in eastern Brazil. South America is, however, far more regular than North America. The only irregularities caused by mountains are in the north, where the Andes system forms the Isthmus of Panama and the small peninsulas of Venezuela. The irregular southern coast is due to sinking of the land; but the coast of Peru and northern Chile is now rising (p. 36).

Summary. — *The mountains of South America have given it a triangular form and one or two peninsulas in the north; elsewhere the coast is very regular, excepting in the south, where there has been sinking.*

(D) *Africa.* — Like South America, Africa has a triangular form and regular outline (Fig. 24). Its outline is determined by mountain uplifts near the coast, which have so raised the interior that it is mainly a broad plateau. Only one eighth of the continent lies

FIG. 23. — Relief map of South America.

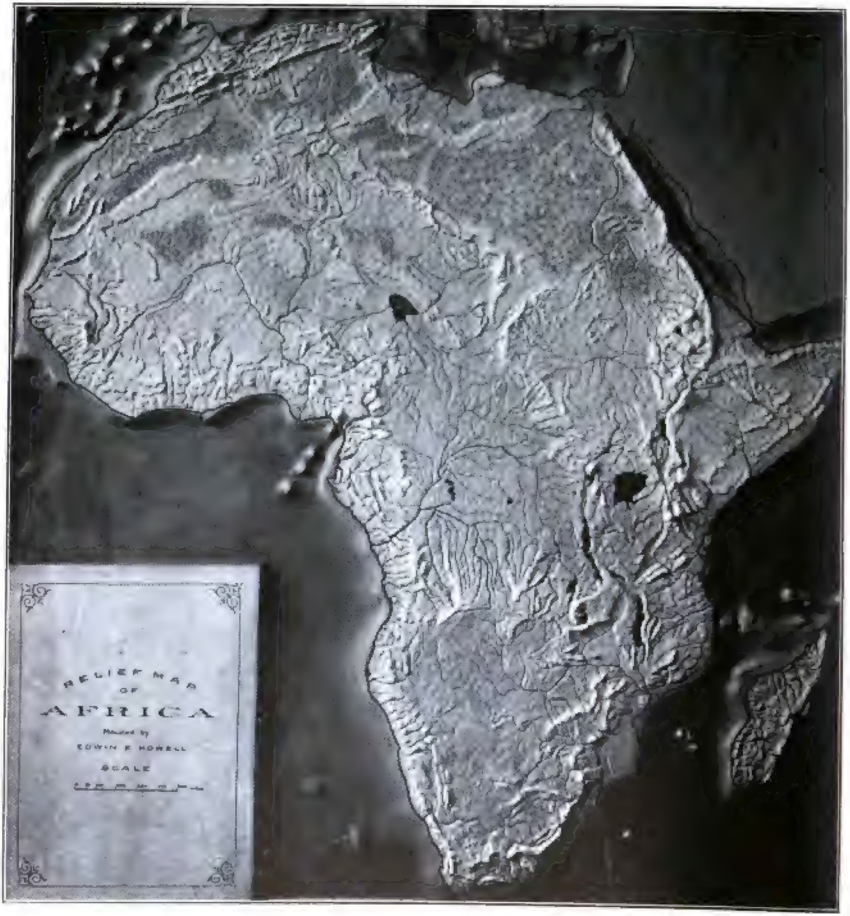

FIG. 24. — Relief map of Africa.

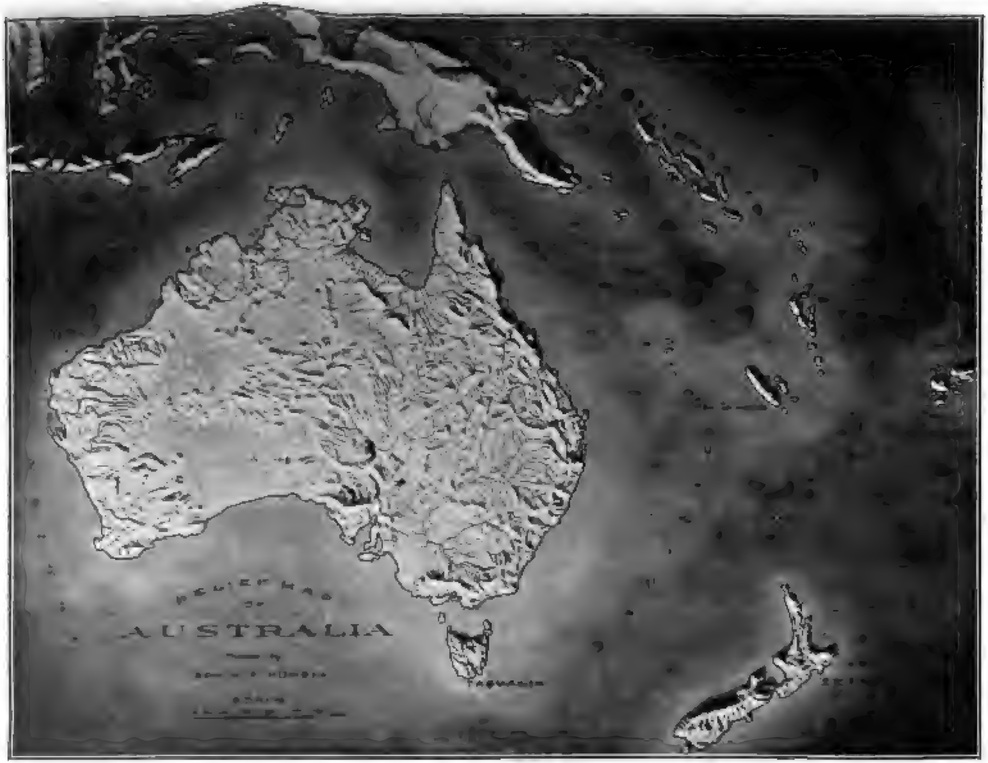

FIG. 25. — The island continent of Australia; also New Zealand, New Guinea, and several chains of islands which are parts of mountain chains in the sea.

FIG. 26. — The great continent of Eurasia.

below an elevation of 600 feet. Madagascar is part of a mountain chain; the peninsula of Tunis is the eastern extension of the Atlas Mountains; and the peninsula of Abyssinia is also due to mountain uplift. There are few harbors, because there has been no extensive sinking of the land.

Summary. — *Africa is a broad plateau, triangular in outline, with mountains near the coast. Its coast line is remarkably regular.*

(E) *Australia.* — The continent of Australia (Fig. 25) is a huge island. A mountain chain in the east, and others in the west, have helped determine its form; but the mountains are not so arranged as to develop a typical triangular shape. York peninsula in the northeast, and the peninsula of Victoria and the island of Tasmania in the southeast, are continuations of the eastern Australia mountains. A sinking of this continent has caused many small bays and excellent harbors.

Summary. — *The island continent of Australia has not the typical triangular form. Mountains and sinking of the land have caused a somewhat irregular coast.*

(F) *Eurasia.* — While the other continents stand out quite by themselves, Europe (Fig. 27) and Asia are so closely connected that they are often considered as one continent. Had the study of geography not started in Europe, it is probable that it would have been called a part of the immense continent of Eurasia (Fig. 26). This great land area has an irregular triangular form, one angle of the triangle being at Bering Strait, the second in Indo-China, and the third in Spain.

Eurasia is such a mountainous land, with mountains extending in so many directions, that its coast line is exceedingly irregular. Its great peninsulas — Kamchatka, Korea, Indo-China, India, Arabia, Greece, Italy, Spain, and Scandinavia — are all due to the presence of mountains. The numerous large islands, including the Philippines, the East Indies, Japan, Sicily, Corsica, Sardinia, and the British Isles, are also parts of mountains. Between these mountain uplifts are inclosed many bays, seas, and gulfs.

Parts of this land, especially northwestern Europe, have been lowered beneath the sea. This sinking has formed the fiords of Norway, the Baltic, North, and Irish seas, and a multitude of estuaries, small bays, and harbors. It has also separated the British Isles from the mainland.

Summary. — *Europe is a part of the great Eurasian continent, which has a rough triangular form. The many peninsulas, bays, islands, etc., are due to mountain uplifts and to sinking of the land.*

(G) *Influence of Continent Forms on Man.* — The separation of the continents has interfered with the spread of man. Their low elevation has been very favorable to mankind. Had the average elevation (2000 to 3000 feet) been as great as the average depression of the oceans (12,000 to 15,000 feet), the greater part of each continent would be too high and cold to support a dense population. The development of men and nations has been influenced in many ways by the continent form, the outline of its coast, the inclosed bays and seas, the islands, and the distribution of mountains and plains.

An irregular coast line favors navigation; and it is an interesting fact that the inhabitants of continents that have regular outlines have advanced far less rapidly than those whose coast has many harbors and bays. Illustrations of these influences and others, on man, animals, and plants, will appear in later chapters.

Summary. — *The elevation, surface features, and coast line of continents have had important influence on man, animals, and plants.*

16. Form of the Oceans. — The continents are clustered around the north polar region, with tongues projecting southward; the ocean water is centered around the south polar region, with triangular tongues projecting northward between the continents (Fig. 29). In outline the oceans are very irregular, because the irregular continents form their boundaries.

We commonly recognize five oceans (Fig. 28). It is customary to choose an arbitrary boundary — the Antarctic circle — for the ice-laden *Antarctic Ocean;* but it is far better to consider as a great *Southern Ocean* (Fig. 29) all the

Fig. 27. — Europe.

THE TWO HEMISPHERES.

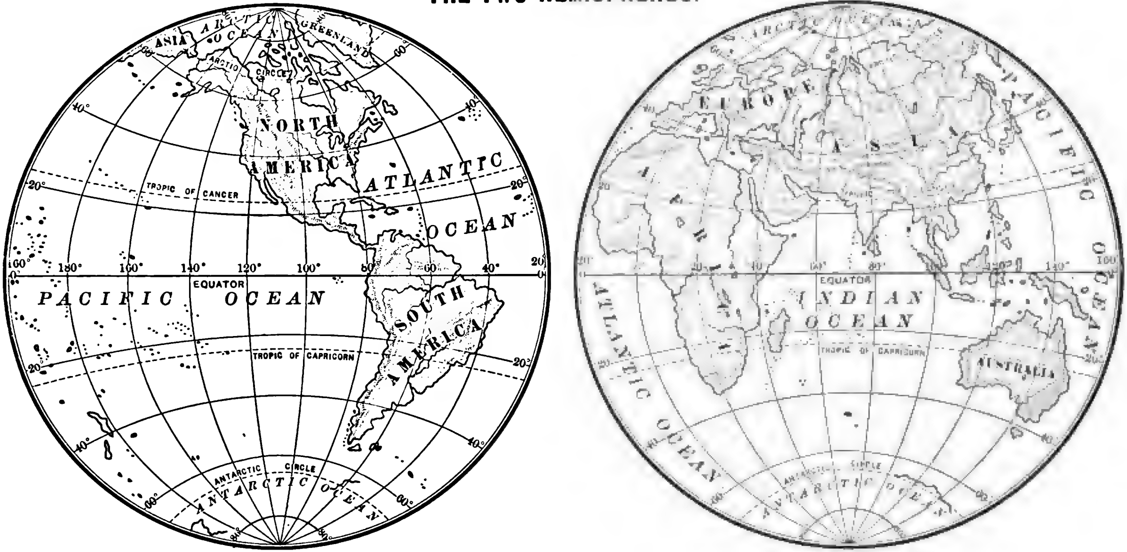

FIG. 28. — The two hemispheres.

water south of Australia, Africa, and South America. Three great ocean tongues extend northward from this Southern

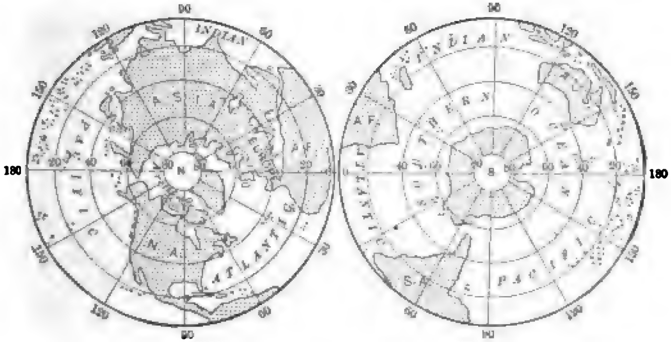

Fig. 29.—The northern and southern hemispheres.

Ocean: (1) the *Indian Ocean*, which reaches up to Asia between Australia and Africa; (2) the immense *Pacific*, which extends up between America, Australia, and Asia, to the point where America and Asia almost meet; and (3) the *Atlantic* tongue, bounded by the Americas on one side and Africa and Europe on the other. The Atlantic is given an hour-glass shape by the narrowing where the projection of South America reaches eastward toward that of Africa. The *Arctic Ocean* is an extension of the Atlantic; it is, in fact, an ice-covered bay, partly cut off from the Atlantic by Greenland and Iceland.

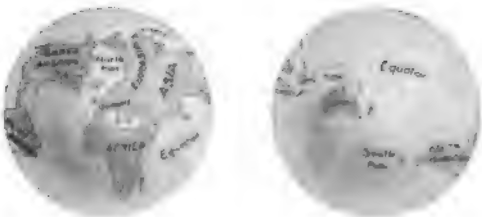

Fig. 30.—The land and water hemispheres.

The northern hemisphere contains the greater part of the land, while the southern hemisphere is essentially a water hemisphere (Fig. 29). By choosing the proper circle, it is possible to so divide the earth as

to have one hemisphere in which most of the land is placed, and the other with little land (Fig. 30). London is very near the center of the land hemisphere.

Now that men no longer timidly skirt the coasts in small boats, but steer boldly out to sea in great ships that visit every ocean, the needs of ocean navigation have led to the making of canals for short cuts across land barriers. Formerly, vessels sailing from Europe to India went all the way around Africa; now they take a short cut across the Isthmus of Suez (Fig. 535). Soon ships from eastern United States and Europe, bound for Asia or western United States, will make a short cut by way of the Isthmian Canal. Thus every day the oceans are becoming more useful.

Summary.—*Most of the ocean water is in the southern hemisphere, three triangular tongues extending from the great Southern ocean northward between the continents. The Arctic is a bay-like extension of the Atlantic.*

Topical Outline, Questions, and Suggestions.

Topical Outline.—8. **The Atmosphere.**—Extent; composition; proof of its existence; importance,—life, fire, decay, diffusion of light and heat, hearing, winds, vapor, wind power; effects on land; soil.

9. **The Oceans.**—Distribution of water; area covered; depth; importance,—animal products, navigation, vapor supply, effect on climate.

10. **The Solid Earth.**—Covering of sea floor; of land; origin of soil; importance; depth; absence on steep slopes; condition beneath the soil mantle; valuable mineral substances.

11. **The Earth's Interior.**—Weight of material of outer part and of interior; proofs of interior heat; former belief; earth's crust; reasons for present belief; effects of pressure; former condition of earth; future.

12. **Air, Water, and Rock.**—(*a*) States of matter: air, water, and rock illustrate the three states; changes of each of these to the other two states. (*b*) Intermingling: rock and water in air; water and air in earth; air and rock material in water.

13. **Irregularities of the Earth's Crust.**—Average depth of ocean basins; average height of continents; proportion of plains; distribution of mountains and volcanoes; amount of irregularity of earth's surface; cause of irregularities; changes in level.

14. **Conflict of Erosion and Elevation.** — Nature of agencies of erosion; effect on land; on sea floor; conflict between erosion and elevation; importance of result upon man.

15. **The Continents.** — (*A*) *Characteristics:* definition; real boundaries; elevation; surface features; drainage; relation of mountains to continent form — illustration. (*B*) *North America:* mountain systems; relation to continent form; to plains and plateaus; to irregular outline; effect of sinking of the land. (*C*) *South America:* mountains; outline; irregularities. (*D*) *Africa:* outline; surface features; coast line. (*E*) *Australia:* position; form; coast line. (*F*) *Eurasia:* relation between Europe and Asia; form of Eurasia; effect of mountains on coast line; of sinking of the land. (*G*) *Influence of Continent Forms on Man:* effect of separation; of low elevation; of coast line.

16. **Form of the Oceans.** — General form and outline; subdivisions of the ocean waters; boundaries of each; land and water hemispheres; value of oceans for navigation.

QUESTIONS. — Section 8. What is the extent of the atmosphere? Name some important effects of the air.

9. What influence has gravity on the oceans? What is the area and depth of the oceans? Of what importance is the ocean for its animal products; for navigation; for its influence on climate?

10. What covers the sea floor? The land? What is the origin of soil? Of what value is it? What is beneath it? Why is it sometimes absent? What valuable materials come from the solid earth?

11. What reasons are there for believing the earth's interior to be highly heated? Why is it no longer believed to be molten? What prevents it from melting? What is the earth's crust?

12. How do the states of air, water, and rock vary? What are the three states of matter? How are air, water, and rock mingled?

13. Compare the ocean depths and continent elevations. What is the general condition of ocean bottoms and continents? Where are mountains found? How many times greater is the earth's diameter than the height of Mt. Everest? What is the cause of these irregularities?

14. What agencies are attacking the land? What effect has this attack on the land? On the sea floor? What conflict is there between opposing forces? How has this conflict been of importance to man?

15. (*A*) What are the characteristics of a continent? What relation do the mountains have to the continent form? Give an illustration. (*B*) Explain the general form of North America. Explain the irregularities of the outline. Give instances illustrating each of the two causes for irregularities. (*C*) What are the characteristics of South America? (*D*) Of Africa? (*E*) Of Australia? (*F*) What is the relation of

Europe to Asia? Explain the irregular outline of Eurasia. (*G*) How has the continent form influenced man?

16. State the distribution of the ocean water: its general distribution; the subdivisions, starting from the Southern Ocean; the meaning of land and water hemispheres. What obstacles have been overcome?

SUGGESTIONS. — (1) In a small jar seal up a plant, being careful to have it well watered, and see if it grows after the oxygen is exhausted. (2) Place a candle in a fruit jar, light it and see if it burns after the oxygen is used up. (3) Why are there holes beneath the wick of a lamp? (4) Have some oxygen generated in the chemical laboratory, and place in it a smouldering piece of cloth. Explain the change that occurs. (5) How deep is the soil in your vicinity? Find some cut — a cellar, railway cut, or stream valley, — where bed rock is seen beneath the soil. How thick is the soil? Of what is it composed? What kind of rock underlies it? Is the line between rock and soil a sharp line? (6) To illustrate the three states of matter: freeze some water. Melt the ice, then evaporate the water over the fire. Where does the water go? Place some water in a shallow pan in a room and watch it from day to day. Where does it go? What becomes of the water that you pour on plants? Of that sprinkled on the city pavements? (7) Stir mud and water together. Have you ever seen a stream resembling the muddy water? Where did the mud come from? Where was it being carried? (8) Carefully weigh a piece of chalk. Soak it in water and weigh it again. Why the difference? Most rocks will illustrate the same thing, but, being less porous, not so well as chalk. (9) Place some salt in water and stir it once in a while. Where has the salt gone? After twenty-four hours pour the water off and evaporate it. Do you find the salt? Chalk, marble, and many mineral substances will dissolve as the salt did, but in smaller quantities. (10) See if there are fossils in the rocks of your neighborhood. If so, find out if they once lived in the sea. What do they prove? (11) In a shallow pan of water build three ridges of pebbles and clay, as high as you can, forming a triangular outline to represent the mountain skeleton of North America. With a sprinkling pot wear them partly down. Draw off the water with a siphon, then make a sketch map of the miniature continent, marking on it the position of the mountain ridges. Compare it with an outline map of North America.

Reference Books. — See references at end of Chapters III, X, and XII; also MILL, *International Geography*, Appleton & Co., New York, $3.50.

CHAPTER III.

CHANGES IN THE EARTH'S CRUST.

17. Relation of Man to the Land. — In a railway journey from Atlantic City, east of Philadelphia, to Chicago a great variety of land forms may be seen. First the seashore; then a lowland plain; then a hilly country; then a wild mountain region, with long ridges separated by broad valleys; then a rugged plateau, with rivers deeply set between steeply rising, wooded banks; then the open plains. Besides these large features many smaller ones are noticeable — rivers, creeks, brooks, rapids, waterfalls, floodplains, lakes, narrow gorges, broad valleys; in fact, all the great variety of land forms to be found in a large area of diversified country.

The careful observer will also note the following facts regarding settlement and industry. The steeper hill and mountain sides are still forested (Fig. 85), and lumbering is the only industry on their rocky slopes. Few houses are seen in the narrow valleys, though here and there a fall has given the site to a mill, or even to a town; and, in a few places, there is some industry connected with the production of valuable minerals from the mountain rocks. On the other hand, the open plains and low hills, both to the east and west of the mountains, are everywhere inhabited; houses are almost always in sight, woods are scattered, farms are seen on every hand, and the land is dotted with villages, towns, and cities.

This route passes three of the eleven largest cities in the United States, — Chicago the second largest, Philadelphia the third, and Pittsburg the eleventh. One is a sea port, one a lake port, and one a river port.

These few facts indicate that there is a relation between the form of the land and the industries of the people. Every educated person should know the causes which operate to so modify the form of the land as to adapt it to different industries. This inquiry belongs to physical geography, or, as it is often called, *physiography*. To truly appreciate this subject it is necessary to carry our inquiry back far enough to understand some geological facts and principles; and to this the present chapter is largely devoted.

Summary. — *There are great differences in the land surface from place to place, and consequently in the industries of man. Physical Geography, or Physiography, studies the causes for these differences and their relation to one another.*

18. Rocks of the Crust.[1] — The many different kinds of rocks in the earth's crust are included in three large classes, — *sedimentary*, *igneous*, and *metamorphic*.

(A) *Sedimentary Rocks.* — Rock fragments — pebbles, sand, and clay — are washed into seas and lakes by rain, rivers, and waves. They settle in the quiet water, the coarser fragments sinking to the bottom first. The motion of the water, agitated by waves and currents, keeps the finer fragments suspended for a longer time, and they therefore sink to the bottom farther from shore. Thus the water assorts the rock fragments according to size.

On some days the waves and currents are weak, on others strong; sometimes the rivers bring little sediment, at other times much. These differences in currents, and in materials supplied, cause the deposit of layers of different kinds, one on another. Each layer is of the kind that waves and currents are able to bring (Fig. 35).

Such layers are called *strata* (singular, *stratum*), and the rock is said to be *stratified*. Some strata are thin, others thick. Sometimes only one stratum is seen in a cliff, while in

[1] Appendix C contains a description of common minerals and rocks.

Fig. 31. — A shale cliff in a gorge. Some of the layers are slightly more sandy than the clay shales which form most of the cliffs.

Fig. 32. — A gravel bank, with some layers partly consolidated, and therefore standing out from the face of the bank.

FIG. 33. — Granite, lower left hand figure; pumice, upper left hand; gneiss, right hand.

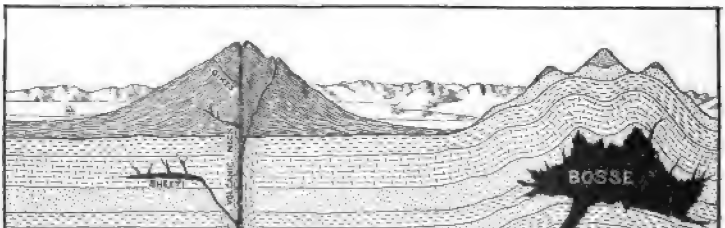

FIG. 34. — To illustrate the origin of igneous rocks. The cone on the left is a volcano, made of lava and volcanic ash.

other cliffs there are strata of different kinds (Fig. 31), possibly shale, sandstone, conglomerate, and limestone.

When the sediment is deposited, it is loose and unconsolidated, like a gravel bank. The pressure of other layers, deposited above, and the action of percolating water, slowly bind the fragments together, forming solid rock. The percolating water dissolves mineral substances in one place, carries them on, and deposits some around the sediment grains. This binds, or cements, the rock

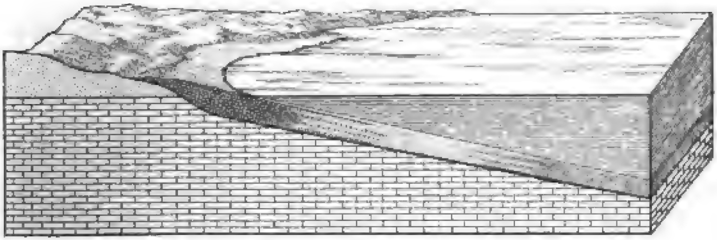

FIG. 35.—To illustrate the deposit of sedimentary rocks. On the extreme left are coarse pebbles; on the extreme right, clay; in the middle, sand. Some layers of pebbles were dragged out to the sand area when the currents and waves were strong; and some sand layers were stratified with the clay strata.

fragments together. The most common rock cements are the common soluble minerals, carbonate of lime, oxide of iron, and quartz. One may often see the process of cementing in a gravel bank (Fig. 32) where a white coating of carbonate of lime has been deposited on some of the pebbles.

Summary. — *Sedimentary rocks are in layers, or strata, formed by the assorting power of waves and currents, which vary in strength and carry finer particles farther from shore than the coarser particles. By pressure and the deposit of mineral cements, the loose rock fragments are bound together, forming solid rock.*

(B) *Igneous Rocks.*[1] — These rocks have risen from within the earth in a melted state. In some cases each eruption produces a lava flow, which cools to form a thick, massive layer of solid rock. In other cases the violence of the eruption

[1] See also Chapter VII.

blows the lava into bits of volcanic ash or porous pumice (Fig. 33). Lava and ash usually build a cone around the volcanic vent or neck (Fig. 34). Such beds are usually less regular and more massive than sedimentary strata.

Much lava fails to reach the surface. Such *intruded* igneous rock is found in various positions, cutting across the sedimentary and other rocks. A narrow crack filled with lava forms a *dike* (Fig. 34); a mass of lava thrust between strata forms an intruded *sheet* or *sill* (Fig. 34); large, irregular masses, rising into the cores of mountains, form *bosses* (Fig. 34). Pikes Peak and Mt. Washington are bosses of hard granite rock (Fig. 33), brought to light by the wearing away of the layers into which they were intruded.

Summary. — *Igneous rocks are formed by the cooling of melted lava, some at the surface, in the form of lava flows and volcanic ash, some as intruded dikes, sheets, and bosses.*

(C) *Metamorphic Rocks.* — When subjected to great pressure, or heat, or both, rocks are changed, or *metamorphosed.* By metamorphism limestone is altered to marble; shale to slate; and sandstone to quartzite. The change may go so far that, as in the case of *gneiss* (Fig. 33) and *schist,* it is often impossible to tell the nature of the original rock. Metamorphic rocks are especially common among mountains where, during the mountain formation, the strata have been subjected to great pressure and heat. These changes have bent, folded, broken, and twisted the layers (Fig. 46), and often completely altered the rocks from their original condition.

Summary. — *When subjected to heat, pressure, or both, as among mountains, rocks are greatly altered, or metamorphosed.*

(D) *Resistance of Rocks.* — All minerals, when exposed to the weather, are attacked by the elements; but there is much difference in the rate at which different ones wear away. Quartz, for example (Appendix C), is hard, only slightly soluble, and does not decay; feldspar is hard and does not dissolve, but decays without great difficulty; calcite is both soft and easily soluble.

The rate of decay of rocks depends in large part on the kind of minerals of which they are composed. Sandstone and quartzite (Appendix C), made mainly of quartz, are very durable rocks; and so is granite, which is mostly quartz and feldspar. On the other hand, limestone and marble, made of calcite, are easily destroyed.

The decay of minerals and rocks is due largely to the action of water (p. 38). Hence dense and massive rocks, like gneiss and granite, are not so easily disintegrated as porous or friable ones, like shale and schist, into which water enters easily. Because of these facts weak rocks are worn away, forming valleys, while durable rocks are left standing to form hills, ridges, and peaks (Fig. 38).

Summary. — *Some minerals and rocks are durable, others weak. Therefore, as the land wears down, valleys are formed where the rocks are weak; hills, ridges, and peaks where they are more durable.*

19. Changes in Level of the Land. — The old ideas, that the hills are everlasting and that the land is firm and stable, are now known to be incorrect. On the contrary, the land is ever changing. Hills are slowly wearing away, valleys are being deepened, and the waste is being carried to the sea.

In addition to this, the crust of the earth is slowly rising in some places and sinking in others. By these movements sea bottoms have been raised to form parts of continents; mountains have been formed; and lands have been lowered beneath the sea. The explanation of these changes is the slow cooling and contraction of the heated interior (pp. 17 and 99).

Evidence of such changes in level during past ages is abundantly preserved in the rocks. Beaches and coral reefs are found many feet above the sea; and fossil remains of ocean animals are entombed in the strata, even of mountains. There is also full proof that changes of level are now in progress. For example: a part of the Scandinavian peninsula, north of

Stockholm, has risen 7 feet in 150 years; the Netherlands are slowly sinking; the coast of New Jersey is sinking at the rate of about 2 feet a century; Eskimo houses in Greenland have been lowered into the sea; the land around the Great Lakes is slowly rising; and in 1822, and again in 1835, the coast of Chile was raised 2 to 4 feet. Hundreds of similar cases are known (Fig. 37).

These changes of level are of two kinds: (1) rapid and local, where mountains are now growing, as in Japan and western South America; and (2) slow and widespread, where large areas slowly swing up or down, as in northeastern America (p. 208). While in some places the lands are sinking, as a general rule they are rising. This has been true for long periods of the past; and, as a result, the continents are very largely made of sedimentary strata that were deposited in ancient seas.

Summary. — *The surface of the land is slowly wearing away; it is also being raised here and lowered there. There are both local, rapid movements and a slow swinging up or down of large areas. On the whole, the continents have been rising, and this is why they are so largely made of sedimentary strata.*

20. Disturbance of the Strata. — The sedimentary strata are deposited in nearly horizontal layers parallel to the sea floor (Figs. 35, 43). When added to the land these strata are usually raised by slow, broadly extended movements which only slightly disturb the original horizontal position (Fig. 31). The plains of the Atlantic coast and the Mississippi valley, and the plateaus of the West, have such horizontal strata.

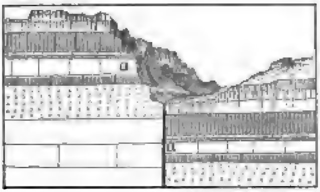

Fig. 36. — A fault. The same layer (*a a*) stands at different levels on the two sides of the fault plane.

Among mountains, on the other hand, the strata are folded and broken by the great pressure. In such cases the layers are no longer horizontal, but are tilted at all angles (Fig. 38).

FIG. 37. — The columns of Jupiter Serapis at Puzzoli (Fig. 201), on the Bay of Naples, Italy. These ruins of an old temple, built on dry land, were lowered beneath the sea, then raised to their present position. Notice the rough surface in the marble columns, reaching about to the height of the wall. This is caused by the borings of a shell (Lithodomus) which bores into the rocks along the Mediterranean coast. These borings prove that the columns have stood beneath sea level up to that point.

FIG. 38. — A ridge in the foothills of the Rocky Mountains. These rock strata were deposited in the sea in a horizontal position, then tilted during the growth of the mountains. They prove change in level as a result of mountain growth. The upper layer is harder than the others, and hence resists the weather better. This is why it stands up so sharply while the weaker layers below are more rapidly crumbling away.

Lava and metamorphic rocks (p. 34) are also common in mountain regions. For these reasons mountain rocks are far more complex in kind and position than those of plains.

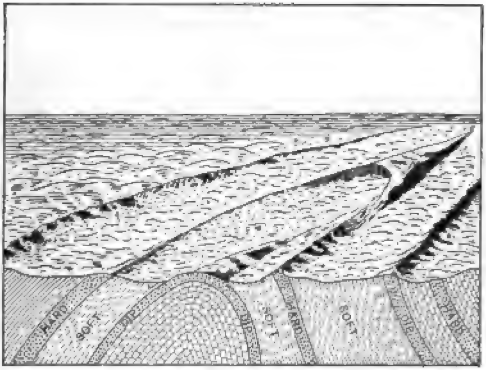

FIG. 39. — An anticline.

Various names have been given to the forms assumed by the disturbed mountain strata. A break in the rocks, accompanied by movement on one side, is known as a *fault* (Figs. 36, 44). An arched upfold of the strata is known as an *anticline* (Figs. 39, 45); a downfold is a *syncline* (Fig. 40). In an anticline the rocks incline, or *dip* (Figs. 38, 39, 45), both ways from the axis of the fold; in a syncline they dip *toward* the axis (Fig. 40). Where a fold has a dip in only a single direction it is called a *monocline* (Fig. 41). Some folds are very regular or *symmetrical* (Fig. 45); others are quite *unsymmetrical* (Fig. 42); and in some, the folding has gone so far that the folds are actually *overturned* (Figs. 42, 48). In very intense folding the strata are sometimes *crumpled* (Fig. 46).

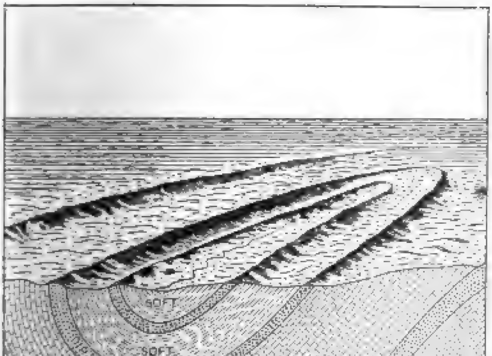

FIG. 40. — A syncline.

During their uplift, rocks are often cracked by the strains. These cracks are called *joint planes* (Figs. 47, 75). The joint planes usually extend vertically into the strata, and consist of two sets, meeting nearly at right angles. Water readily enters along these natural planes of splitting (Fig. 51), which therefore aid in disintegrating the rocks. Joint planes are of great importance in quarrying, for they make natural breaks which aid in splitting out blocks of stone.

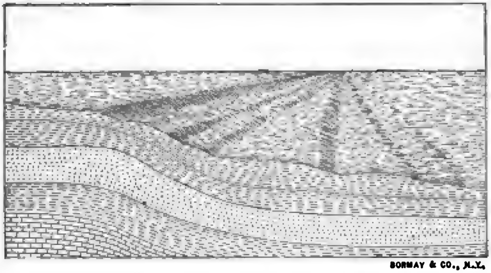

Fig. 41. — A monocline.

Summary. — *In plains and plateaus the uplifted stratified rocks are commonly left in nearly their original horizontal position; but in mountains they are folded and faulted. Joint planes, or natural planes of breakage, are also produced by the strains.*

21. Agents of Weathering. — When exposed to the air, rocks crumble and fall apart as wood and nails do. This disintegration, or *weathering*, is due to the action of various agencies, the most important of which are percolating water, air, and the action of animals and plants. These agencies do some of their work by dissolving and decaying minerals, some by mechanical means, as when rocks are ruptured by frost.

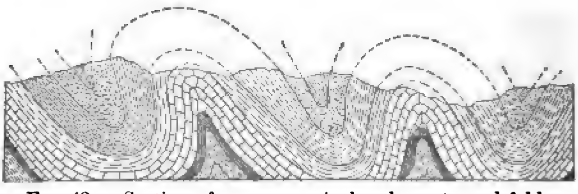

Fig. 42. — Section of unsymmetrical and overturned folds.

Summary. — *Rocks crumble, or weather, by the mechanical and chemical action of percolating water, air, and animals and plants.*

FIG. 43. — Horizontal strata in the West. A hard layer, standing out as a low cliff, may be seen in the foreground and far along the hillside.

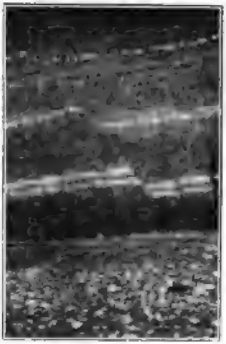

FIG. 44. — A fault. Notice that the layers do not match on the two sides of the fault plane.

FIG. 45.— A symmetrical anticline.

Fig. 46. — Crumpled layers in Canada. Notice how contorted they are.

Fig. 47. — Joint planes on the shores of Lake Cayuga, New York. The two sets, almost vertical, meet at nearly right angles. The smooth faces of the cliff are due to the fact that the rock has cleaved away from it along the joint planes.

22. Work of Underground Water. — A portion of each rain sinks into the soil, and part of it percolates into the rocks, for underground water is able to enter even the densest of rocks. Some of this water enters along joint planes (Figs. 51, 54); some between the rock grains; and some along the cleavage planes of the minerals.

FIG. 48. — A small, overturned fold — both a syncline and an anticline.

In moist climates, shallow wells find this underground water even in rock; and upon it farms and entire towns and villages depend for drinking water. It is underground water, too, that the roots of plants seek in the soil. Without it they die. Its presence is further shown by springs, which are places where underground water rises to the surface in some quantity (p. 59).

Underground water finds many mineral substances which it is able to take away in solution. Its power of solution is greatly increased by carbon dioxide, and other substances, which it obtains from the air and from decaying vegetation.

Aided by oxygen, carbon dioxide, and other substances, the underground water also causes changes in composition of many minerals. These changes are not very unlike that which causes a shiny nail, when exposed to dampness, to decay to a yellow, powdery iron rust. By these changes some substances are produced which the percolating water can carry off in solution. The roots of plants seek and obtain

some of these soluble mineral products, which are *plant food.* This decay, together with removal of portions, causes minerals and rocks to crumble.

In cold climates the mechanical work of water is of importance in disintegrating rocks. The water, in the soil, in the joint planes, and in the microscopic rock crevices, freezes in winter. When water freezes it must expand; and, as a bottle breaks when water freezes in it, so in winter the rocks are often broken by frost action. This frost work is an important agent of rock disintegration (Figs. 49, 52, 54).

Fig. 49.—A mountain top, showing the rock shattered by frost action.

Summary. — *Water percolates into soil and even rock. It dissolves some minerals, changes others, and thus causes the rocks to disintegrate. In cold climates, frost also aids in disintegration.*

23. Influence of Air in Weathering. — Warming causes rocks to expand, and cooling causes them to contract. A fire built against a rock, for example, causes it to expand and crack. In hot deserts the warming of rocks by day, and cooling by night, are important means of disintegrating them.

The oxygen and carbon dioxide of the air, taken underground by water, help in the work of disintegration; they also cause changes in damp soil and rock at the surface.

Summary. — *Air helps in rock disintegration by its changes in temperature and by supplying oxygen and carbon dioxide.*

24. Organisms as Agents of Weathering. — The roots of plants help to pry rock materials apart. In their search for water and

plant food, the roots and tiny rootlets enter any crevice to be found (Fig. 53). On growing larger they exert such a pressure on the walls of the crevices as often to rupture them. In this way soil is pulverized and rocks broken apart.

The ash left when wood is burned is largely mineral matter that the roots have taken as plant food. This proves that plants remove mineral substances from the soil and rock, and therefore that they help in disintegration. They aid also by supplying carbon dioxide and organic acids to water which, on soaking into the soil, passes through decaying vegetation.

Animals are likewise effective agents of weathering. This is especially true of burrowing animals, such as earthworms, moles, ants, woodchucks, and prairie dogs. They stir up the soil, thus making it more open to the entrance of water; they bring soil to the surface, thus exposing it to the weather; and some, like the earthworms, take soil into their stomachs, grinding it a little as it passes through. Earthworms are among the most important of agents in soil preparation.

Summary. — *Weathering is aided by plant roots, which pry off fragments and remove mineral substances; by carbon dioxide and organic acids, supplied from decaying vegetation; and by the action of burrowing animals, especially earthworms.*

25. Rate of Weathering. — Because the weather has completely destroyed their form, it has been necessary to replace certain stone ornaments (gargoyles) that were placed on the Lincoln Cathedral, in England, about seven centuries ago. On the other hand, delicate scratches on rocks, made by glaciers not less than 5000 years ago, are still perfectly preserved wherever they have been covered by a foot or two of soil (Fig. 289). These facts show that the rate of weathering is slow, but that it varies with circumstances.

The *nature of the rock* is one cause for difference in the rate of weathering. Some rocks disintegrate quickly, others slowly.

Another cause for variation is *climate.* Where there is little moisture, as in deserts, there can be little change due to frost, solution, or decay, and weathering is, therefore, very slow. An obelisk (Fig. 50), which had stood for over 3000 years in the

desert climate of Egypt, began to decay so rapidly when removed to the damp climate of New York that it was necessary to protect it with a glaze. In cold climates, frost action is very active; in hot, damp climates the abundant vegetation supplies organic substances to the warm percolating water, greatly aiding it in its work of changing and dissolving the minerals.

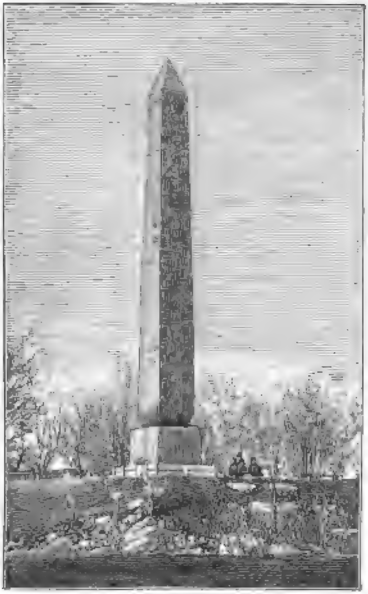

FIG. 50.—The Obelisk in Central Park.

Exposure is also of importance in determining the rate of weathering. Even a thin soil cover protects the rock from the weather. Rock fragments, loosened by weathering, remain on level surfaces and gentle slopes, forming a protecting soil blanket. But on steep slopes, from which the fragments fall away as fast as they are loosened, the rock is kept constantly exposed to the elements (Figs. 54, 57). Therefore, cliffs, precipices, and mountain slopes are places of relatively rapid weathering. That the rocks are crumbling is proved by the fact that every now and then a fragment falls from the cliffs (Fig. 57); but, even in the most favorable places, weathering is so slow that one might see no great change in a lifetime. Centuries are required for great changes.

Summary. — *Even under the most favorable conditions, weathering is very slow. Its rate varies with the rock, climate, exposure, and steepness of slope. Steep slopes are especially favorable because the falling away of loosened fragments leaves the rocks exposed.*

26. Results of Weathering. — Without question, the most important result of weathering is the formation of soil.

Fig. 51. — A shattered rock surface showing many cracks into which water is able to enter.

Fig. 52. — Percolating water seeping out of the rock and freezing.

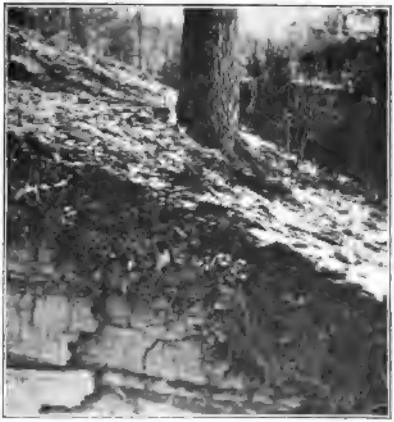

Fig. 53. — The roots of a tree prying open the rock of a ledge.

FIG. 54. — A steep peak in the high Alps where frost action is powerful. Notice the many cracks in the rock. Water enters along these, and every now and then a fragment breaks away and falls to the base.

While some of the crumbling rock is removed in solution, there is a remnant, or *residue*, which cannot be dissolved. This remnant forms *residual soil* (Figs. 55, 56), which sometimes mantles the rock to a depth of over a hundred feet. A large part of the land is covered by residual soil, resting on the rock whose decay produced it. Other kinds of soil are those brought by wind, by rivers, and by glaciers. Such soils are not residual, but transported.

FIG. 55. — Residual soil. A few rounded pieces of solid rock remain, not yet completely disintegrated.

Weathering supplies mineral substances for underground water

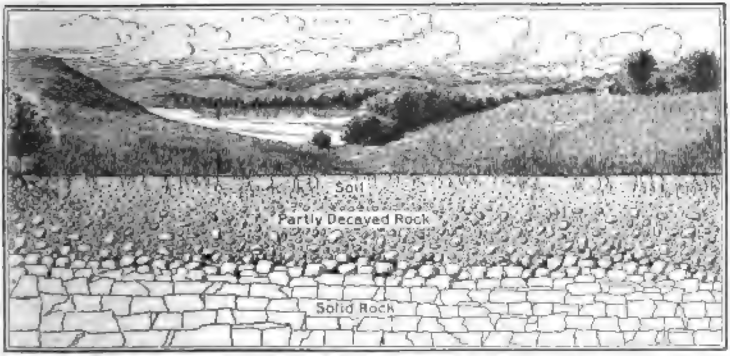

FIG. 56. — A diagram to illustrate the formation of residual soil. Notice that the soil is finer near the surface, where roots and earthworms penetrate, and that it grades downward into solid rock.

to remove in solution. It is this that gives "hardness" to water, and the valuable properties to many mineral springs. One of the most common of these dissolved mineral substances is carbonate of lime, which supplies corals and shell-bearing animals with the lime from which beds of limestone are made in the sea.

Rock fragments, loosened from cliffs by weathering, gather at the base, forming *talus slopes* (Figs. 57, 66). Occasionally great masses are loosened, falling as *landslides* or *avalanches* (Figs. 58, 161, 162). There is also a very slow, almost imperceptible movement of rock fragments down even gentle slopes. It is this that makes the streams muddy.

These rock fragments are used by the rivers as tools (Fig. 57) in cutting their valleys; and, on reaching the sea, they are deposited as beds of sedimentary rock (p. 32). By this removal of rock fragments and dissolved mineral substances, supplied by weathering, valleys are being slowly broadened.

Finally, weathering is a delicate tool of rock sculpturing. It easily discovers which rocks are weak, and which durable; and, by removing the weaker rocks faster, it etches the durable strata into relief (Figs. 38, 59). The importance of this fact is more fully shown in later chapters.

Summary. — *Among the important results of weathering not already described are,* (1) *the formation of residual soil, or soil of rock decay;* (2) *the supply of soluble mineral substances to water;* (3) *the formation of talus and avalanches;* (4) *the supply of cutting tools to rivers;* (5) *the supply of materials for the formation of sedimentary strata;* (6) *valley broadening; and* (7) *rock sculpturing.*

27. The Agents of Erosion. — Besides weathering, which disintegrates the rock, thus preparing it for removal, there are several agents of *erosion* which remove and deposit rock fragments. The work of these agents is fully stated in other chapters and now requires mere mention.

These agents are: (1) *wind*, especially active along the coast (p. 219) and in deserts (p. 87), where there is little vegetation

FIG. 57. — Talus at the base of a cliff (Black Canyon of the Gunnison, Colorado), falling into a torrential river which carries much of it away. As these rock fragments are rolled along the river bed they help to wear the rock away and thus aid in deepening the valley.

Fig. 58.—An avalanche at Quebec, just beneath the fortress, which destroyed a number of houses.

Fig. 59.—A view in the Colorado Canyon, where the cliffs have been sculptured by weathering and erosion, bringing the hard rocks into relief, and giving the softer strata more gentle slopes.

to protect the soil; (2) *rivers* (Chapter IV), everywhere at work removing materials supplied by weathering, and at the same time often deepening their own valleys with the rock fragments that they carry; (3) the *ocean*, whose waves, tides, and currents attack the land along the coast (Chapter XI), and in which sediment washed from the land is deposited (pp. 32, 180); (4) *lakes*, which resemble oceans (p. 220); and (5) *glaciers* (Chapter VIII), at present important only in high mountains and in the frigid zones.

Summary. — *The agents of erosion — wind, rivers, ocean, lakes, and glaciers — remove and deposit rock fragments.*

28. Denudation. — The combined work of the agents of weathering and erosion may be called *denudation*. By denudation the lands are being sculptured (Fig. 59) and their general level lowered. If the material removed by the Mississippi River were taken equally from every part of its drainage area, the surface of the valley would be lowered one foot in 6000 years.

Opposed to this tendency to wear the land away is the constant change in level of the land (p. 35), by which plains are being raised above the sea, plateaus made higher, and mountains uplifted (p. 21). These uplifts are continually giving denudation new work to perform. Were it not for this elevation of the land, it is probable that the continents would have long since been reduced nearly to sea level; for the age of the earth is very great.

Summary. — *Denudation is the combined work of weathering and erosion. It tends to lower the land; but, though the age of the earth is great, frequent uplift has prevented it from lowering the continents to the condition of a level plain.*

29. Age of the Earth.[1] — No one knows how old the earth is. But all who have studied the question are agreed that it cannot be less than many millions of years, and most geologists hold that it must be at least a hundred million years. The evidence of this vast age cannot be stated in an elemen-

[1] For a list of the geological periods, see Appendix D.

tary book; but the following facts may help the student to understand why it seems a necessary conclusion.

So slow is the work of denudation that a person living by a river side, or on the seashore, may see no notable change, even in a lifetime; yet careful study will show that slow changes are in progress. Geological study has proved that such slow changes have accomplished great results in the past; and this could not have happened unless there had been a great length of time.

Among these evidences of great changes are the following. The Colorado River has slowly cut a canyon over a mile in depth. Lofty mountain ranges once existed where New York and Philadelphia now stand; but they have been slowly worn away. Volcanoes have also been worn down to their very roots. To have slowly accomplished these great results demands vast periods of time. Sedimentary rocks furnish evidence leading to the same conclusion. It requires years for a layer of sediment a foot thick to be deposited; yet some sections reveal 40,000 feet of strata that were deposited in ancient seas.

From these geological facts the conclusion that the earth is vastly old seems inevitable; and the inference is supported by evidence furnished by physicists and biologists. Consequently, all geologists and physical geographers are now as convinced on this point, as astronomers are that the sun and stars are millions of miles away. To really appreciate the conclusions reached in the following pages, the student must start out with the same belief.

Summary. — *Evidence furnished by geologists, physicists, and biologists proves that the age of the earth is many millions of years.*

Topical Outline, Questions, and Suggestions.

Topical Outline. — 17. **Relation of Man to the Land.** — Changes noted on a railway journey: larger features; smaller features; industries; cities; relation between land form and industries.

18. **Rocks of the Crust.** — Three divisions. (A) *Sedimentary rocks:* manner of deposit; terms used: consolidation. (B) *Igneous rocks:* on

the surface; intruded into the crust. (C) *Metamorphic rocks:* cause; results; metamorphism in mountains. (D) *Resistance of rocks:* differences in minerals; in rocks; effect on land form.

19. **Changes in Level of the Land.** — Slow wearing away; movements of the crust; cause; proofs, — from rocks, from present changes; instances; two classes of movements; effect on continents.

20. **Disturbance of the Strata.** — Original position; position in plains; in mountains; fault; anticline; syncline; dip; monocline; unsymmetrical fold; overturned fold; crumpling; joint planes; importance.

21. **Agents of Weathering.** — Agents at work; nature of process; result.

22. **Work of Underground Water.** — Entrance of water; proof of its presence, — wells, plant roots, springs; solution; substances aiding solution; changes in minerals; result; plant food; frost action.

23. **Influence of Air in Weathering.** — Heat and cold; effect of oxygen and carbon dioxide.

24. **Organisms as Agents of Weathering.** — (*a*) Plants: mechanical work of roots; removal of mineral substances; aid to underground water. (*b*) Animals: kinds; work done; earthworms.

25. **Rate of Weathering.** — Illustrations of differences in rate; effect of rock; of climate, — arid, damp, cold, warm and damp; of exposure, — gentle slopes, steep slopes; slowness of weathering.

26. **Results of Weathering.** — Residual soil; other soils; dissolved mineral substances; talus; avalanches; supply of tools to streams; formation of sedimentary strata; valley broadening; rock sculpturing.

27. **The Agents of Erosion.** — Winds; rivers; ocean; lakes; glaciers.

28. **Denudation.** — Definition; tendency; effect of uplift.

29. **Age of the Earth.** — Probable age; reasons for belief; illustrations; importance of grasping the conception.

QUESTIONS. — 17. What land forms are seen on a journey from Philadelphia to Chicago? What relation between land forms and industries?

18. What are the three divisions of rocks? (A) How are rock fragments assorted by water? What is the meaning of the terms strata, stratum, and stratified? How are stratified rocks consolidated? (B) In what conditions are igneous rocks accumulated on the surface? Describe three kinds of igneous intrusions. (C) What is the nature of metamorphism, and its results? Why is it so common in mountains? (D) How do minerals vary in durability? What two conditions influence the rate of rock disintegration? What effect has this on the form of the land?

19. What changes are in progress on the earth's surface? What evidences are there of past and present changes of level? What is the nature of these movements? What effect has this on the continents?

20. Why are the strata of plains commonly horizontal? What is the condition in mountains? Define fault; anticline; syncline; dip; monocline. Draw diagrams to illustrate symmetrical, unsymmetrical, and overturned folds. What are joint planes? Of what importance are they?

21. What are the agents of weathering and how do they work?

22. How does underground water enter the rocks? What proofs are there of its presence? In what two ways does it work chemically in disintegrating the rocks? How does it work mechanically?

23. In what ways is the air effective as an agent of weathering?

24. In what ways do plants aid in weathering? Animals?

25. Give illustrations of differences in rate of weathering. State the three chief causes for differences. What effect has exposure?

26. How is residual soil formed? What other kinds of soil are there? State the other effects of weathering.

27. What work is accomplished by the agents of erosion?

28. What is denudation? How is it opposed?

29. What evidence is there that the age of the earth is great?

SUGGESTIONS. — (1) Imitate sedimentation in a glass dish. Place sand, pebbles, and clay in the dish with water. Stir vigorously and let it settle. Sprinkle on the water a handful of sand, clay, and pebbles. (This experiment may be made even more effective if a mixture of sand, pebbles, and clay is made to represent land, then washed with a sprinkling pot into a glass aquarium partly filled with water.) Where does the finest material settle? Are the layers horizontal? Vary the rate of washing and observe what happens. (2) Even if the rocks and minerals in Appendix C are not studied, specimens of quartz, feldspar, calcite, sandstone, limestone, granite, and marble should be studied. The last four can be obtained readily, probably in a stone yard. The three minerals may be purchased from a mineral dealer for a very small sum. Do not get valuable specimens, but buy by the pound and break it up for class use. Study the characteristics mentioned in the Appendix. (3) Are the rocks of your neighborhood horizontal or tilted? If the latter, can you find folds or faults? Describe what you find. Look for joint planes and study them; take their direction with a compass; does water escape from them? Are there any quarries in which they are of use? (4) Find specimens of rock in the fields, or elsewhere, showing weathering. What signs of weathering do you find? Are there red or yellow stains? What causes them? (5) To prove that water expands on freezing, fill a bottle with water and freeze it. Even a toy cannon, plugged tightly, would break. (6) Place a thin piece of stone in a fire. Does it crack? Heat another small piece slowly, then cool it quickly by placing it in cold water. These experiments illustrate the

expansion with heat and contraction with cold, though of course in nature the changes are not so great as this. (7) Look for illustrations of roots prying rocks apart. This may best be seen on cliffs where trees are growing. Tell what you see. (8) Watch the earthworms. The "casts" left when they are driven out of the swollen ground after a heavy rain are made of earth from their stomachs. What evidence do you find that earthworms help in weathering? Darwin considered them of enough importance to write a book on them. (9) If you live in a glaciated country (Fig. 270), look for glacial scratches recently uncovered. Are they fresh? Why? Look for others uncovered for a longer time. Are they fresh? Why? (10) Study the soil of your vicinity carefully and tell its characteristics. (11) If you can find a cliff, look for a talus slope. Of what is it made? Are the fragments angular or round? Are they all of the same kind of rock as the cliff? Have any fragments been removed by water? Have any fallen recently? Go there in spring, when the frost is coming out of the ground, and see if there have been recent falls. (12) If the water of your vicinity is hard, find out if mineral is deposited in tea kettles or in engine boilers. Perhaps the teacher of chemistry may suggest a way of proving that there is mineral in the water. (13) Are any of the streams that you know receiving rock waste from the valley sides? When does most come? Watch the streams to see. Does this sediment prove that denudation is now in progress? Would much change take place in a year? In a century? In a million years? Think of this carefully.

Reference Books. — LYELL, *Principles of Geology*. 2 vols., Appleton, & Co., New York, 1877, $8.00; GEIKIE, *Text-book of Geology*, Macmillan Co., New York, 4th edition, 1903, $7.50; DANA, *Manual of Geology*, American Book Co., New York, 1895, $5.00; LECONTE, *Elements of Geology*, Appleton & Co., New York, 1903, $1.00; TARR, *Elementary Geology*, Macmillan Co., New York, 1902, $1.40; SCOTT, *Introduction to Geology*, Macmillan Co., New York, 1902, $1.90; GEIKIE, *Class Book of Geology*, Macmillan Co., New York, 1886, $1.10; BRIGHAM, *Text-book of Geology*, Appleton & Co., New York, 1901, $1.40; MERRILL, *Rocks, Rock Weathering, and Soils*, Macmillan Co., New York, 1897, $4.00; SHALER, *Origin and Nature of Soils* (p. 219), 12th Annual, U. S. Geological Survey, Washington, D.C.

CHAPTER IV.

RIVERS AND RIVER VALLEYS.

30. Supply of Water. — Part of the rain water returns to the air by evaporation, part sinks into the ground, and part runs off. That portion which passes back to the air need not be considered here. Most of that which sinks into the ground (p. 39), eventually returns to the surface by slow seepage and from springs. It may continue for months on its slow underground journey before finding conditions that favor its return to the surface. Were it not for this steady source of supply, after each rain rivers would quickly dry up. Then river navigation would be stopped, river water power would frequently fail, and the water supply of many cities would be cut off for a large part of the time.

From a third to a fourth of the rain water runs off at the surface. Therefore every rain swells the volume of the streams, adding greatly to the steady supply from underground. When the snow melts or the rains are heavy, the rivers may be quickly transformed to raging torrents (Figs. 60, 61).

The presence of the forest tends to reduce floods. Its dense undergrowth, the mat of decaying vegetation, and the tangle of roots seriously interfere with the run off of the water. There is a greater run off (1) during heavy rains than during long, slow drizzles; (2) on clay soils than on sandy soils; (3) on frozen soils than on those with no frost.

Some rivers have their water supply regulated. This is true of those whose supply comes chiefly from large and copious springs (p. 59). Lakes act as regulating reservoirs, out of which streams flow with little change in volume; thus the volume of Niagara is almost always the same. Swamps also help to regulate the water

FIG. 60. — A waterfall in a dry summer, when even the underground supply was limited (a part of the water has been led off for use in a mill).

FIG. 61. — The same as Fig. 60 after a heavy rain.

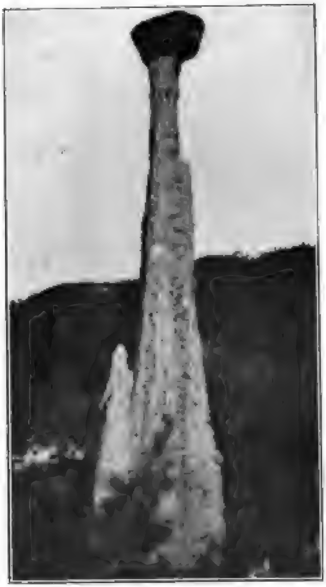

FIG. 62. — A rain-sculptured earth column in the Tyrol of Austria. The bowlder which caps it helps to protect the clay beneath.

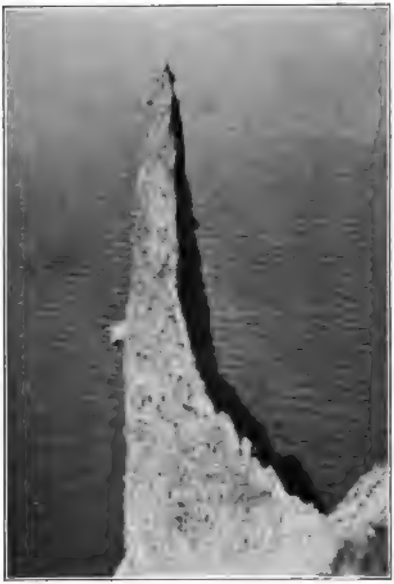

FIG. 63. — A rain-sculptured column in a clay cliff on the shore of Lake Ontario, in New York.

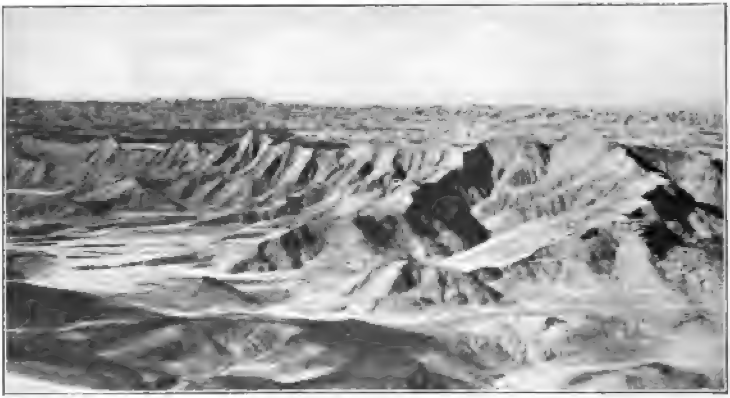

FIG. 64. — A view in the Bad Lands of South Dakota where, as far as one can see, the surface is rain-sculptured.

supply. Glaciers regulate the flow of many mountain streams; but the melting in summer greatly increases their volume.

Summary. — *Underground water gives to streams a steady supply; the rains and melting snows increase their volume. The forest, nature of the rain, soils, and frost influence the run off. Springs, lakes, swamps, and glaciers tend to regulate the volume of rivers.*

31. Rain Sculpturing. — The surface of a road or a plowed field is often gullied by the washing action of rains and rain-born rills. The material removed is carried on toward the larger streams. In moist countries (Figs. 62, 63) this rain sculpturing is not usually so noticeable as in arid regions where there is little vegetation to protect the soil. Loose clayey soils are deeply gullied by the occasional heavy rains of arid regions; but there is so little weathering that the steep slopes are not greatly rounded. Such rain-sculptured lands are known as *Bad Lands*, one of the largest sections being in South Dakota (Fig. 64). They are unfit for agriculture, and even for cattle raising. Where the forest has been cleared for centuries, as in parts of Greece and Italy, rain sculpturing has destroyed much farm land.

Summary. — *In arid lands, and where the forest has been removed, the land is sometimes so gullied by rain sculpturing as to unfit it for agriculture. In the West such regions are known as Bad Lands.*

32. The Rock Load of Rivers. — To the mineral load which is brought in solution by underground water (p. 39) is added some which the river water dissolves from its bed. This dissolved load is sometimes very noticeable, as when river water is "hard," or, as in southwestern United States, even salt or alkaline.

Fragments of rock, loosened by weathering (Figs. 57, 66), or washed in by the rain, are also carried by rivers. Water buoys up these suspended rock fragments so that they lose about one third of their weight. A current moving at the rate of one and a half or two miles an hour, that is about half as fast as a man walks, will transport small pebbles; one moving a quarter of a mile an hour carries only clay. In

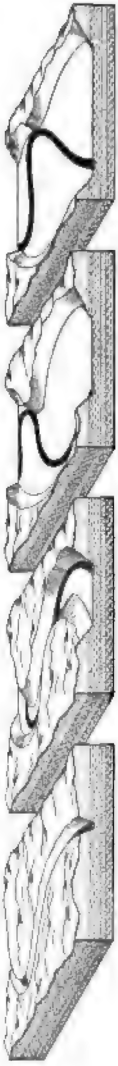

FIG. 65. — Four diagrams to illustrate valley broadening by lateral swinging.

mountain torrents bowlders weighing hundreds of pounds are swept along; but only sand and clay can be moved over level lowlands.

These rock fragments are used as tools of erosion. The grinding of pebbles together rounds them and gradually wears them down to sand and clay; and the river bed is also worn away, or eroded, by the grinding of these fragments against it.

The load which rivers bear may be judged from the following. The Mississippi River annually carries to the sea 7,500,000,000 cubic feet of sediment. This would make a prism one mile square at the base and 268 feet high. It also carries 2,850,000,000 cubic feet of mineral matter in solution. Other rivers are bearing similar loads. From this it is evident that rivers are performing a great task of removing rock waste from the lands.

Summary. — *Rivers bear great loads of minerals in solution; also rock fragments, whose size varies with the velocity of the currents. These are used as tools of erosion.*

33. Erosive Work of Rivers. — Rivers aid in lowering the land by removing the materials supplied by weathering and by rain wash. At some time in their history most of them are also at work in a vigorous attack on their channels. This work is both chemical (corrosive) and mechanical (corrasive), and it results in the formation of river valleys.

Streams cut their banks (Figs. 69, 70) as well as their beds. This lateral cutting causes the valley to be broader than the river itself (Figs. 65, 67). This is especially true where

FIG. 66. — The Gunnison River, Colorado. Rock fragments from the cliffs have made a talus, which, sliding into the river, supplies it with tools for work (see also Fig. 57). A railway follows this narrow valley, one of its bridges being seen in the distance. To pass along this gorge it has to wind about, crossing the stream by bridges and tunneling the rocks.

FIG. 67. — A narrow gorge (Enfield) in central New York. One wall of a pot hole is seen in the foreground on the left. The stream course is here guided by two joint planes which cause the smooth, straight walls between which the water is flowing.

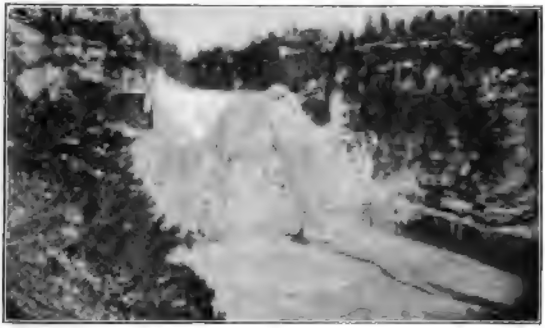

FIG. 68. — Ice in the same fall as Figs. 60 and 61.

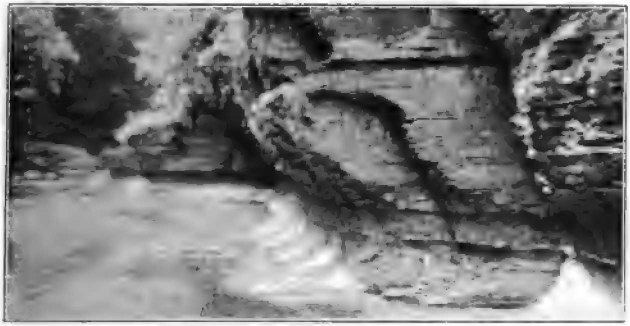

FIG. 69. — A stream swinging against and undercutting a shale cliff, showing lateral erosion in a gorge where the stream is also rapidly deepening its bed.

FIG. 70. — Lateral swinging of a stream against a clay bank, which is caused to slide into the stream. In this way the valley is being broadened.

FIG. 71. — Watkins Glen in central New York. A small stream is cutting this gorge deeper. It is a succession of rapids and cascades, at the base of which pot holes are being cut in the shale. One fairly large pot hole appears in the near foreground; others are seen farther upstream.

the river swings against loose material which slides into the stream (Fig. 70).

The rate of valley deepening varies greatly according to the rock, the slope, and the volume. A stream naturally cuts faster in soft than in hard rock; on steep slopes than on gentle slopes; with great volume than with small volume. The effect of difference in volume may be seen in many streams, which at ordinary times do little work of erosion, but when in flood become powerful erosive agents (Fig. 61).

Since sediment supplies rivers with cutting tools, this also has an important effect on river erosion. When there is little sediment, erosion is greatly reduced. For example, Niagara River emerges from Lake Erie as clear water, the sediment having been deposited in the lake. Therefore, down to the Falls, the river has been able to do very little toward cutting a valley (Fig. 483). The Colorado River, on the other hand, with a heavy load of sediment, has cut an enormous canyon (Figs. 1, 477), which it is still rapidly deepening.

Other rivers, like the lower Mississippi, have more sediment than they can carry, and must deposit some of it, building up their beds. Rivers that are deepening their valleys are said to be *degrading* (Fig. 71), those that are building up their beds are *aggrading* their valleys (Fig. 112).

Joint planes also influence the rate of erosion, and sometimes direct the course of a stream (Fig. 67). Ice (Fig. 68) is likewise of importance. In winter it diminishes the supply of water; but in spring its melting adds to the floods; and it pries and breaks off fragments of the rock and carries them along.

Summary. — *Rivers cut vertically on their beds, and laterally at their banks, the rate varying with the rock, slope, volume, and sediment supply. Some rivers are aggrading, others degrading their valleys. Joint planes and ice also influence river work.*

34. Waterfalls. — When a stream is degrading its bed, conditions are often discovered which cause the formation of

rapids and falls. Most commonly it is a difference in hardness of the strata. Soft rocks are cut more rapidly than hard, and therefore rapids and falls occur where a degrading stream flows from a hard to a soft layer. Such falls are very common in regions of horizontal strata, where hard layers (Fig. 72) retard erosion while weaker layers beneath are removed. This undermines the hard layer, and when a piece breaks off, the fall retreats upstream (Fig. 75), always being located on the steep edge of the hard stratum (Fig. 74). There are thousands of illustrations of this, of which Niagara, located on a hard layer of limestone (Fig. 482), is the largest and best.

Falls and rapids cause streams to concentrate their energy in spots. This is well illustrated by Niagara, where the falling water has excavated a deep hole at the base of the fall. Similar holes, called *pot holes* (Figs. 67, 71, 73), are common in streams that are degrading their beds. They are enlarged and deepened by the whirl of water, which carries pebbles about with it. Pot-hole work is an important factor in the excavation of valleys.

Waterfalls and rapids are of great importance in supplying power, the water being led through canals or pipes and allowed to fall upon a wheel which turns machinery. Now that electricity is used for power, falls are of value even in sparsely settled regions. Niagara Falls power, transmitted by wire, lights and runs the cars of Buffalo; falls in the Alps and Sierra Nevada supply electric power for places miles away.

Summary. — *Falls and rapids, of use for water power, are common where a degrading stream flows from a hard to a soft stratum, as at Niagara. Pot holes are excavated by the falling water.*

LIFE HISTORY OF A RIVER VALLEY

A river valley, like an animal or plant, changes as it grows older. To understand these changes, or the life history of a river, it seems best to start with simple conditions — a plain of moderate elevation, with nearly horizontal strata,

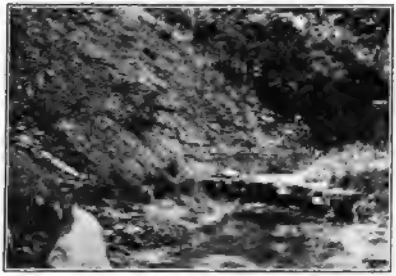

Fig. 72. — A hard layer of rock in a stream bed. When the water is higher there is a fall here, and the falling water removes the softer layer from beneath, undermining the hard stratum.

Fig. 73. — The man is standing in a pot hole. In the bottom there are small round stones which the water whirls about, grinding out the rock and thus deepening and enlarging the hole.

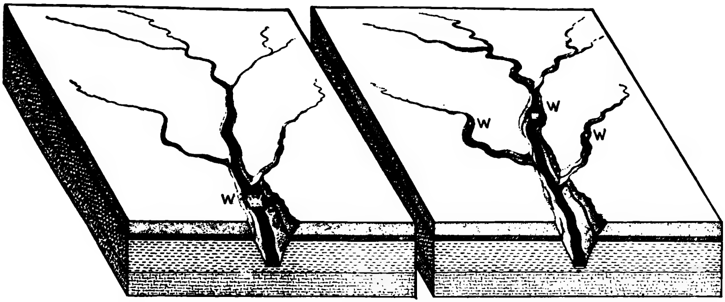

Fig. 74. — Two diagrams to illustrate the history of a waterfall. In the left hand figure a hard stratum (the darkest) has a waterfall (W) over its edge. As the falling water undermines this hard stratum the fall retreats upstream, always being located on the hard layer. At a later stage, therefore, (right hand figure) the fall is farther upstream; and falls are also present on the same layer in two tributaries. The stream erosion has formed a deep gorge below the fall, as in the case of Niagara.

FIG. 75. — Taughannock Falls near Ithaca, New York, 220 feet high. The angles and smooth rock faces near the upper part, and the angle in the crest of the fall, are caused by joint planes. A few years ago a huge block fell from the crest of the fall, giving its present shape; before that, the crest of the fall projected downstream.

and a moist climate. Later study will show that many rivers depart from such an ideally simple condition; but these variations will be better understood if we first study a simple case. Such a study will reveal some important laws of valley formation.

35. Young Stream Valleys. — On such a plain as that just described the drainage is at first somewhat indefinite. Water fills the depressions in the plain, forming shallow lakes; and large expanses of the level plain form flat-topped divides, often swampy, because there has not been time enough for many tributaries to develop. Wherever water runs off, it flows in consequence of the natural slope, or has a *consequent course*. Florida (Figs. 78, 79) has such a condition of drainage.

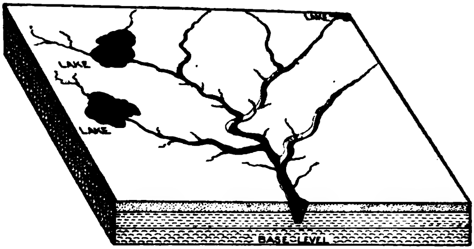

FIG. 76. — A young stream valley on a plain. It has not yet reached base level; the divides are flat-topped; there are few tributaries; and lakes still exist.

The consequent streams quickly cut into the plain, forming narrow, steep-sided valleys (Fig. 76). As they degrade along their beds they discover differences in hardness of the strata, and therefore develop falls (Fig. 74) and rapids. At the same time weathering and meandering slightly widen the valley.

There is a limit below which no part of a stream may deepen its bed, and this is called its *base level* (Fig. 81). The sea is the permanent base level, and the down-cutting of every stream that enters the sea is arrested by it. Lakes act as temporary base levels; but their effect does not last long, because the sediment that the streams bring, quickly fills and destroys them (p. 164).

While the lakes are being filled and the valleys deepened, tributaries are developing. Little by little the tributary streams gnaw their way back from the main stream, narrowing the flat-topped divides and in time draining the level, swampy areas.

A stream with these characteristics — steep-sided valleys, waterfalls, lakes, illy defined divides, and tributaries only partly developed — is a *young stream.* It has not had long to work, and consequently its valley is not thoroughly developed; it is still growing. A young stream is better developed in its lower portion than above, as a young tree has a thick, strong trunk and delicate, growing branches. The Niagara Gorge (Fig. 483) and Colorado Canyon (Fig. 1) are good examples of young stream valleys (see also Figs. 77, 80); but no lakes remain in the course of the Colorado.

Although such valleys are young, the time required to perform even this much work is long measured in years. A river may have been working for 5000 or even 50,000 years, and yet have a valley with the characteristics of youth. As in the case of plants, some of which grow old in a few days while others require weeks or even years, so in river valleys there is a great difference, under different circumstances, in the time required to pass the stage of youth. Yet in all cases the features of youth are so distinct that a young valley is hardly more difficult to distinguish than a young plant.

Summary. — *A young river is one that has not had a long time for development. It, therefore, has a steep-sided valley, few tributaries, indefinite divides, and, if conditions favor, waterfalls and lakes. The term "youth" does not refer to years, but, as in plants, to form.*

36. The Grade of a Stream.—The lowest grade to which a stream can cut its channel is one down which it is just able to carry its sediment load. The grade line is a curve, reaching base level at the river mouth and rising rapidly near the divide (Fig. 81). All streams that have not reached grade are working toward it, and young streams, which have a

Fig. 77. — Narrow gorge of a young stream cut in hard rock. Even here the valley has been widened somewhat by meandering and by weathering. The latter cause accounts for the breadth of the gorge at the top.

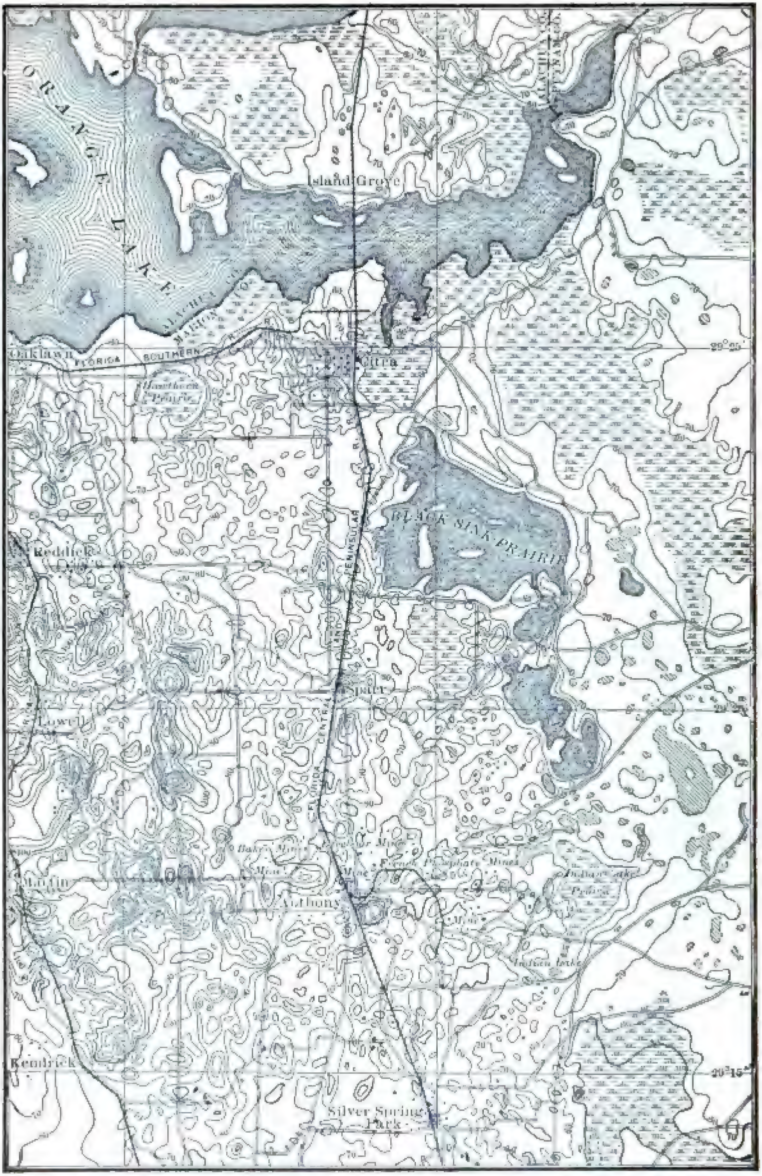

Fig. 78. — Map of a part of the Florida plain where the swamps (indicated by ⁎⁎) and lakes have not yet been drained by the young streams (see Fig. 79). The lines are contour lines. The meaning of these is explained in Appendix I. (Part of Citra, Fla., Topographic Sheet, U. S. Geological Survey.)

FIG. 79. — A flat-topped, swampy divide in the Florida plain, on which the drainage is so young that the tributary streams have not had time to gnaw back and narrow the divide so as to drain the swamps (see Fig. 78).

FIG. 80. — A young valley (on the right of the center) cut in soft material. The sliding down of the sides has broadened this valley. (Contrast with Fig. 77 in hard rock.)

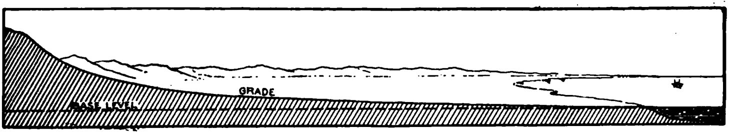

FIG. 81. — Diagram to illustrate the meaning of grade and base level.

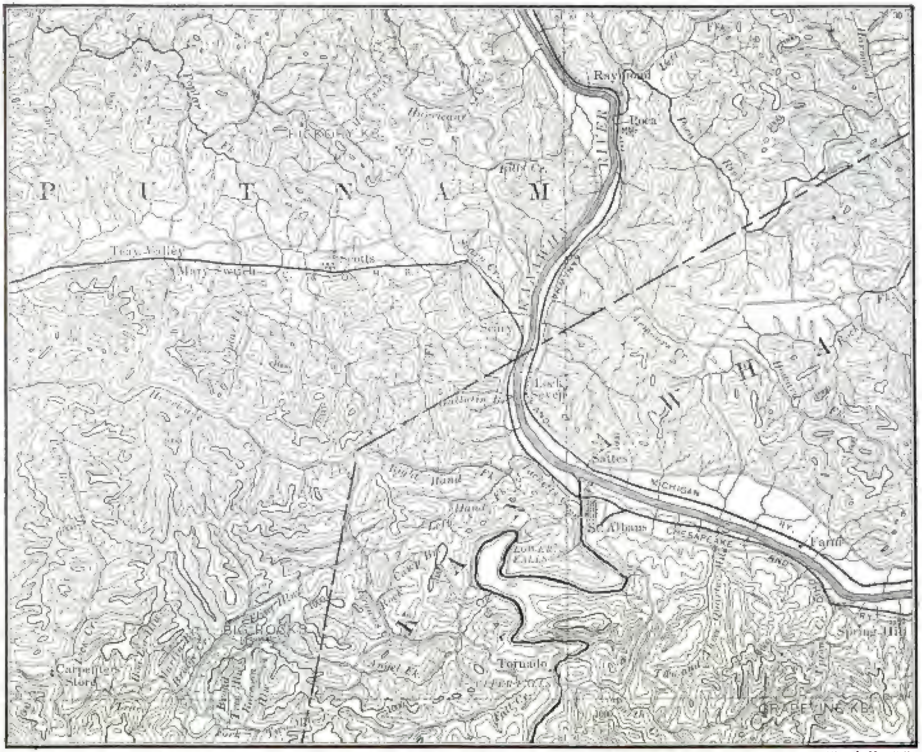

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FIG. 82.—Mature valleys in West Virginia. Here there are no lakes, the divides are narrow, the valleys broad, and there are so many tributaries that all the land is drained. Contrast with Fig. 78. (Part of Charleston, W. Va., Topographic Sheet, U. S. Geological Survey.)

steeper slope than necessary, are actively degrading their beds toward grade. It often happens, however, that a stream has too gentle a grade to move its sediment load over. Then, to secure a steeper grade, deposit is made. Most streams on broad floodplains are thus aggrading their valleys.

Summary.—*The grade of a stream is the lowest slope over which the water can move its sediment load. Young streams are degrading their valleys toward this grade; but many streams are engaged in aggrading their course to secure a steeper grade.*

37. Mature Valleys. — When grade is reached by a river, further down-cutting ceases; but weathering of the valley sides continues. This slowly broadens the valley, wearing the sides back and making the slopes less steep (Figs. 83, 85, 86). The broadening of the valley is first accomplished near the mouth; but it slowly extends upstream. Young streams exist for a long time among the headwaters, as young twigs appear on the outer branches of even an old tree.

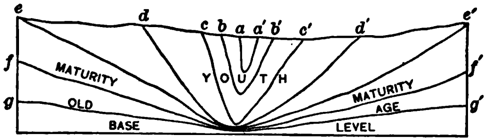


FIG. 83. — To illustrate the broadening of valleys from youth to old age.

In a mature stream, grade has been reached throughout most of its course, and any lakes that may have existed have long since been filled. Nor can there be waterfalls, because the graded stream is no longer cutting into the rock.

Tributaries have developed in such numbers that the divides have become well defined, and all water that falls on the land finds slopes ready for it to flow down (Fig. 82). Again the comparison may be made to a tree, which at first has a trunk and few branches, but, as it grows older, develops an increasing number of minor branches and twigs.

By the development of so many tributaries the number of

slopes and the amount of surface exposed to weathering are greatly increased (Fig. 84). These increasing slopes may supply so much sediment to the main streams that they cannot carry it all to the sea. They then begin to aggrade their courses to establish a steeper grade down which to carry the sediment. In doing this they build floodplains (p. 61).

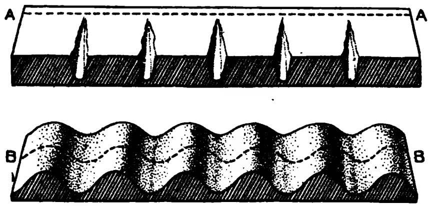


FIG. 84. — To illustrate the increase in slopes as valleys broaden. The line *A A*, drawn on the level surface of a young plain, gradually lengthens to *B B* as the valleys broaden to maturity.

Summary. — *A valley with moderately sloping sides, a fairly well established grade, no lakes waterfalls or rapids, well-defined divides, numerous tributaries, and floodplains in its lower portion is mature.*

38. Old Valleys. — As valleys grow older, the slopes become more and more gentle (Fig. 83) until the surface is reduced almost to sea level. An old land surface, reduced to the condition of a low, rolling surface, is called a *peneplain* (almost plain).

Many parts of the continents are ancient enough to have become peneplains; but there are numerous accidents which commonly interfere with this result. Of these accidents the most important are uplifts of the land, which continually give to streams new tasks to perform. Therefore, few valleys have passed the stage of maturity.

Summary. — *Old valleys are so broad that the surface is reduced almost to a plain, or to a peneplain; but uplift of the land is so frequent that few regions have reached this condition.*

39. Importance of Valley Form. — Young valleys encourage some of man's activities and interfere with others. The waterfalls furnish power; and the lakes are valuable for navigation, for their influence on the climate of neighboring land, and as sources of food-fish and ice. On the other hand, land

FIG. 85.—Railway crossing the Appalachians along one of the narrow, winding mountain valleys, so steep that the forest has not been removed. This valley has the form of late youth, or early maturity.

FIG. 86.—The Connecticut, at Northampton, Mass.; a broad, mature valley, with gently sloping sides, dotted with farms.

Fig. 87. — An underground river in Howe's Cave, New York (copyright 1889, by S. R. Stoddard, Glens Falls, N.Y.).

Fig. 88. — Spring where water pours out from a limestone cavern in Iowa.

cut by young valleys is difficult to cross, the valley bottoms furnish poor grades for roads and railways (Figs. 57, 66, 71, 77), and much of the country is unfitted for agriculture.

In contrast to young valleys, mature valleys are the seats of agriculture, and their fertile floodplains are among the best farm lands of the world. Travel across country is easy, and the river valleys are important highways (Figs. 85, 86). Even the rivers themselves, if large, have such a gentle grade that they are navigable. Thus, flourishing farms and thriving towns and cities line the river banks and dot the slopes of mature valleys. This is well illustrated along the Mississippi valley, which offers a striking contrast to the young Colorado valley (Fig. 1).

Summary. — *Young valleys are unfavorable for occupation; but mature valleys are adapted to agriculture and dense settlement.*

40. Springs and Underground Channels. — Where conditions are specially favorable, underground water (p. 39) is led back to the surface, appearing as a spring. Sometimes it comes out along a porous, sandy layer, sometimes along a joint plane. There are many springs along rivers; but they occur also on hillsides and, in fact, wherever favorable conditions direct underground water to the surface.

Some large and permanent springs rise from deep in the ground through fault planes, often bringing heated water to the surface. Such springs often have so much mineral in solution that they are known as mineral springs, and have important medicinal properties. The Hot Springs of Arkansas, and the mineral springs of Saratoga, Carlsbad, and Vichy, are examples of such springs.

Water percolating through soluble rock, like limestone, dissolves the rock along joint planes and bedding planes. This often results in the formation of long, irregular underground valleys, or caverns, like that of Mammoth Cave, Ky. In such a country much of the drainage is underground (Fig. 87).

There are large surface streams with few tributaries, the chief water supply coming from the springs (Fig. 88) that bring the cavern water to the surface.

Entering such a cavern, one passes through a maze of dark, irregular passages, in which it is easy to lose oneself. From the roof hang *stalactites* (Figs. 87, 91) of carbonate of lime, which the water dissolved in its passage through the limestone rock and deposited on emerging into the cavern. In form they resemble icicles. *Stalagmites* (Fig. 91) are built up from the cavern floor by the dripping water, as ice columns are formed under a spout.

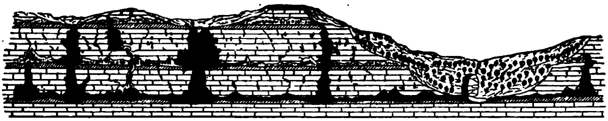


FIG. 89.—To illustrate the formation of limestone caves. Water entering the sink holes has formed great vertical cavities, and also horizontal caverns through which it flows, emerging in the form of springs near the natural bridge on the right.

Often the stalactites and stalagmites unite to form columns (Fig. 91), and sometimes, as in the Luray Cave, they assume weird and even beautiful forms.

The surface of a limestone country is pitted with saucer-shaped depressions, known as *sink holes* (Fig. 90). Through these the water drains into the ground, though sometimes the entrance into the ground is clogged, changing the sink hole to a pond. These sink holes are caused by settling of the ground, due to solution of the rock beneath (Fig. 89).

Weathering, lowering the surface, slowly wears away the cavern roofs. Sometimes only a small part of the roof is left, spanning the valley as a *natural bridge* (Fig. 92).

Summary.—*Springs occur where conditions direct underground water to the surface, for example, a porous layer, a joint plane, fault plain (many hot or mineral springs), or a cavern outlet. Caverns occur where underground water dissolves passageways through soluble rock like limestone. The water enters the ground through*

FIG. 90. — A sink hole, near Luray Cave, Virginia. The water flows into the sink hole from all sides and disappears into the ground.

FIG. 91. — A column in a cavern, formed by the union of a stalactite and a stalagmite.

Fig. 92. — Natural Bridge, Virginia. This bridge is a part of an old cavern roof, the remainder having been removed by weathering.

Fig. 93. — Four views of the same stream at different stages, from low water to the time of flood when the floodplain is completely overflowed. Then a deposit is being made, raising the level of the plain very slightly. (L. O. Towne, Haverhill, Mass., Photographer.)

Fig. 94. — A small ox-bow curve in a meadow brook. A cut-off has been started, but brush was put in to stop it from continuing. (L. O. Towne, Haverhill, Mass., Photographer.)

Fig. 95. — The same as Fig. 94 with the cut-off completed in spite of the brush. (L. O. Towne, Haverhill, Mass., Photographer.)

sink holes, passes along an underground course, and emerges as a spring. It deposits stalactites, stalagmites, and columns in the caverns.

41. River Floodplains. — Streams are often bordered by level plains, built of sediment which they have brought. Even a mountain torrent, that is degrading its bed, may have narrow patches of such deposits on one or both sides. Rivers that are aggrading their courses are always bordered by such alluvial plains, or *floodplains*. They are usually bordered by bluffs (Figs. 96, 97, 102), against which the river cuts as it swings over the floodplain. These, being higher and drier than the floodplain, are often selected as the sites for towns and cities, as in the case of Vicksburg on the Mississippi.

FIG. 96. — Canadian river, Oklahoma. Through this floodplain the river sweeps in great curves between bluffs which are seen in the foreground and in the far distance.

Broad floodplains are due to the fact that there is more sediment than can be carried down the grade. Therefore some must be deposited. When such rivers rise and overflow their banks, they submerge the neighboring lowland (Figs. 93, 99), and, with each flood, deposit a layer of sediment, as mud is deposited on a sidewalk when the gutter overflows. This slowly raises the level of the floodplain; and, since it is being built by a broad sheet of water, its surface is made fairly level.

Many broad floodplains, like that of the Mississippi (p. 327), are very fertile; and frequent overflow, by bringing new soil,

helps to keep them so. Their levelness and dampness further fit them for agriculture. In many arid regions the river water is led out over the floodplains for the purpose of irrigation, and in some arid regions, as along the Nile, the overflows themselves take the place of rainfall.

A floodplain is usually highest near the river, because this part is most frequently reached by floods. This higher portion is known as the *natural levee.* On it are farms, towns, and cities; for example, New Orleans; but behind it is a low, swampy tract, too wet for habitation. At New Orleans, the natural levee is only a few feet above the river level and the swamp. To protect the towns and farms from overflow, men build still higher embankments, or *levees,* which serve to hold back many of the floods. When, however, a great flood breaks through the levee, vast areas are inundated, property is destroyed, and lives lost. Along the Mississippi, such a break is known as a *crevasse.*

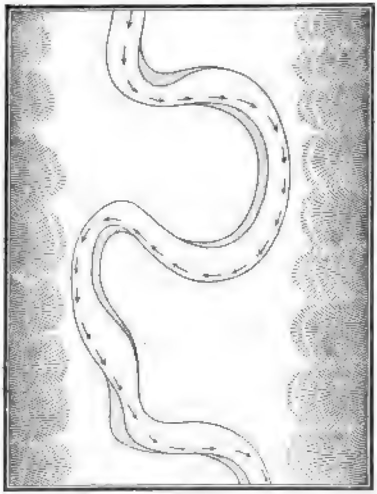


FIG. 97.—To show by arrows how, in meanders, a river current cuts against one bank and deposits on the other. The bluffs are shown on the two sides of the floodplain.

No river flows in a perfectly straight line. On the contrary, irregularities in the bed, and other causes, turn the current toward one side, and cause the stream to cut first at one bank, then at the other (Figs. 70, 102). This starts a curving or swinging of the river, known as a *meander* (Fig. 97), named after a river in Asia Minor (Fig. 345) whose lower course is very meandering. Floodplains are peculiarly favorable to the development of meanders because of the low, level land and the loose sediment, which is easily moved by the water. While

FIG. 98. — A meandering river in India, swinging in broad curves through its floodplain.

FIG. 99.—The Ohio River in flood near Parkersburg, West Va. Notice that the water rises to the first-story windows.

FIG. 100.—An abandoned ox-bow curve in the Connecticut valley near Northampton, Massachusetts.

FIG. 101.—River terraces being cut by a degrading stream in the Andes of Peru.

the stream cuts on one bank it deposits sediment on the other (Figs. 97, 102), and thus forms a broad, sweeping curve known as the *ox-bow curve* (Fig. 98). The curves vary in size with the volume of the river (Figs. 93, 98), being in the Mississippi fully five miles in diameter. As the meandering continues it often happens that the stream cuts across the neck of a curve and abandons it (Figs. 94, 95). The lake thus formed is called an *ox-bow cut-off* (Fig. 100). Floodplains have many such abandoned meanders in all stages of destruction by filling. On the Mississippi floodplain there are places where the river course has been shortened fifteen miles by a single cut-off.

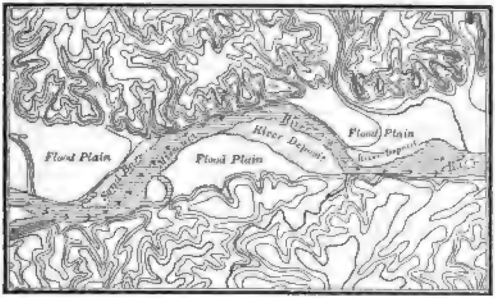


FIG. 102. — The Missouri, a meandering river bordered by floodplain, and cutting at the base of its bluffs, wherever the current swings against them.

Summary. — *Large floodplains are level tracts of fertile alluvial land bordering rivers. They are built during floods by the deposit of sediment, and are usually bordered by bluffs cut by the river. They are highest near the river, at the natural levee, on which artificial levees are built. Over the floodplain the river swings in meander curves, sometimes abandoning them, forming ox-bow cut-offs.*

42. River Terraces. — The swinging of a river causes it to be first on one side of its valley, then on the other. If it is degrading, it cuts downward, now in one place, now in another. This leaves *terraces*, or narrow, flat-topped strips, each faced by a steep slope on the side toward the stream (Figs. 101, 103).

If an uplift elevates a floodplain so that the river cuts down into it, a series of very perfect terraces is carved in the soft floodplain deposits. During the removal of any other kind of soft deposits, such as glacial and lake deposits, rivers also carve perfect terraces.

River terraces are often excellent farm land. The soil is good; they are well drained; the surface is level; and, in arid countries,

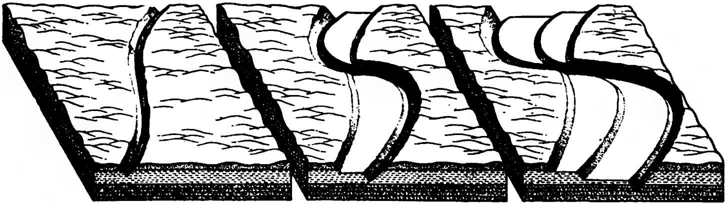


Fig. 103.—Three stages of a degrading river, to illustrate the formation of terraces. Describe these.

irrigation ditches are easily led over their tops. Some of the best farm land in the Connecticut valley is terrace land.

Summary.—*River terraces are flat-topped strips of land with steep front, bordering rivers. They are formed during the removal of materials, especially soft materials, by a degrading stream.*

43. Deltas.—On entering the sea or a lake, a river finds its current suddenly checked. Some of its sediment is removed by waves and currents, but much is deposited in the quiet water near its mouth, building up land. To this land the name *delta* is applied, because of the resemblance to the Greek letter delta (Δ), as seen in the Nile (Fig. 104).

Fig. 104.—The delta of the Nile. The shaded area is reached by floods.

Deltas have the triangular shape because a single channel will not carry all the water over their level surface. For this reason the river divides into channels, or *dis-*

tributaries (Figs. 104–106), which spread apart and enter the sea by separate mouths. The delta surface, though very level, has a gentle grade down which the river water can flow.

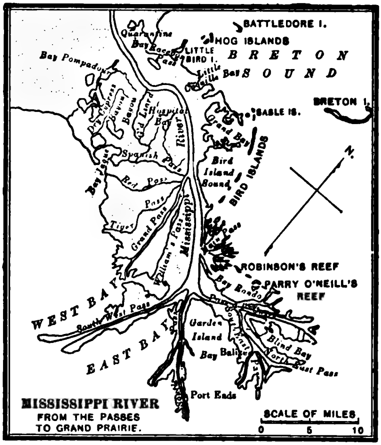


FIG. 105. — The Mississippi Delta.

Deltas are absent from many coasts; for example, northeastern America and northwestern Europe. This is because there has been such recent sinking of the land that there has not yet been time enough to build deltas. It is where the sea bottom is remaining at one level, or slowly rising, that deltas are most common. They are more easily built where the water is shallow than where it is deep, and this is one reason why they are so common in lakes (Figs. 107, 297). Absence of tides and large waves is another reason for so many deltas in lakes.

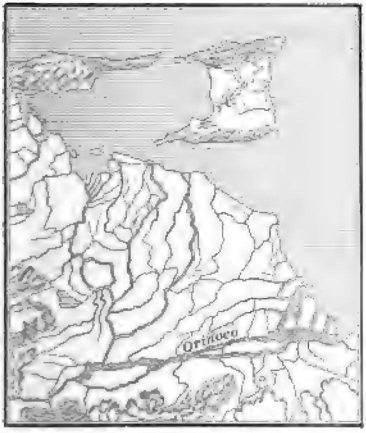


FIG. 106. — The Orinoco delta. Notice its triangular form between the outer distributaries.

Rivers meander on deltas, as on floodplains. Indeed, deltas are so like floodplains that, as they grow outward, their upper parts are commonly called floodplains. They make excellent farm land, and a large percentage of the human race is now living on deltas and floodplains.

The densest population of China and India is centered on the deltas and floodplains of the great rivers, and a large part of Holland is on the delta of the Rhine. The low ground, and the danger of floods from sea and river, make living in such situations dangerous. Millions of people in India and China have been drowned during floods; but the other attractions are so great that these river-made plains are densely settled.

Summary.—*Deltas are level plains, built up by the deposit of sediment at river mouths; they are commonly triangular in shape because crossed by branching distributaries. They are especially well developed in lakes and other places where the water is shallow, the bottom not sinking, and waves and currents not strong. Like floodplains, they form excellent farm land, and are densely settled.*

45. Alluvial Fans.—A stream flowing from a steep to a more gentle slope has its velocity checked. If it has much sediment, some may be deposited where the slope changes (Fig. 109). Such a deposit is called a *cone delta*, or *alluvial fan*. Some are small, with steep slopes (Fig. 108); in fact, they may be seen forming at the base of clay banks after a rain; and some are very large and fairly level, covering areas of thousands of square miles. They resemble deltas in their triangular outlines, and some of the larger ones are difficult to distinguish from deltas (Fig. 110).

As in a delta, the water flows over an alluvial fan in numerous shifting distributaries (Figs. 108, 110, 111). As soon as one channel becomes too high, it is abandoned and a lower portion of the fan is built up. Thus the fan is built up regularly, because all parts of it are reached by the water.

Mountainous arid lands are especially favorable to the formation of alluvial fans, because there are many steep slopes, much sediment, and usually a small amount of water. At times there are heavy floods, bringing much sediment; but at other periods the water disappears by evaporation or by sinking into the gravel.

Fig. 107. — A delta at Menaggio, on Lake Como, Italy. Here a town is built, because on the mountainous coast of this lake few other places than the deltas are level enough for towns.

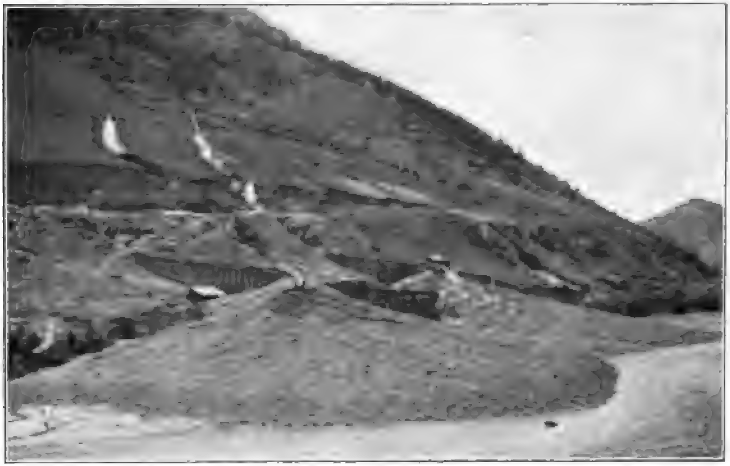


Fig. 108. — Two alluvial fans being built of gravel dropped at the end of sluices in the process of washing gold from the gravels. Notice the numerous branches of the stream on the farther fan. These are so rapidly depositing and building up the fan that they must frequently change positions.

Fig. 109. — An alluvial fan at Chamonix in the Alps, built at the mountain base by torrents bringing materials from the steep mountain slopes.

Alluvial fans sometimes grow out across a valley, damming the main stream and forming a lake (Fig. 113). Tulare Lake in California (Fig. 114), for example, is caused by the low alluvial fan of King River, which descends from the Sierra Nevada to the plain of the valley of California.

Large alluvial fans are excellent farming land. In arid regions, like western United States, they are often irrigated because (1) the soil is good; (2) there is a supply of water at the upper part of the fan; and (3) there is a good grade down which to lead the water. The large, delta-like alluvial fan at the mouth of the Hoangho of China (Fig. 110) is the seat of a dense agricultural population. The frequent shiftings of the river over this fan have caused enormous loss of life by drowning, and by the famines that have resulted from the destruction of crops. Even in a single flood over a million people have been killed. The Hoangho has even been used as a weapon of war, being turned out of its course to prevent an invading army from approaching.

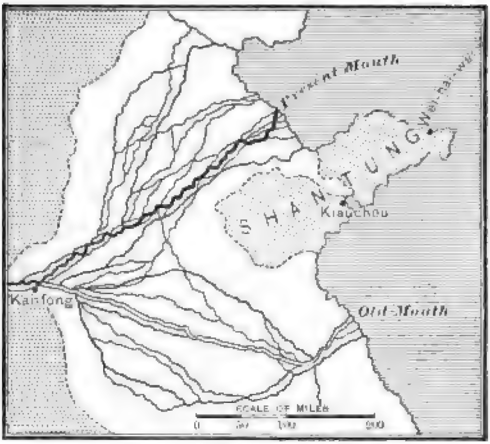


FIG. 110. — Map of the immense alluvial fan of the Hoangho. Measure with scale of miles the distance between the old and present mouth.

Summary. — *Alluvial fans are delta-like deposits made where streams descend from steep to gentle slopes, as at the base of mountains. Large alluvial fans are important agricultural lands.*

45. The Filling of Valleys. — Many valleys are having their bottoms raised by the wash of sediment from their sides (Figs. 111, 113). This is especially true in arid regions

where there is much sediment and too little rain to carry it off to the sea.

The valley of California, 400 miles long and 50 to 80 miles wide, furnishes a good illustration (Fig. 114). From the Coast Ranges and the Sierra Nevada the rain wash and the streams are dragging sediment down the mountain slopes. This action builds broad, flat, alluvial fans (Fig. 113) near the mountains, and still more level deposits farther out in the valley.

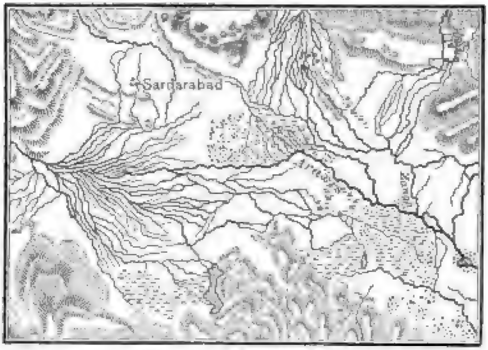


Fig. 111. — The distributaries of several alluvial fans, filling a valley among the mountains near Mt. Ararat.

A similar case is that of the Po valley in northern Italy. It was once an arm of the sea between the Alps and the Appennines, but it has been filled by wash from these mountains, and is still being built out into the Adriatic. The many mountain streams are forming low alluvial fans of coarse gravel near the mountains; but near the Po the sediment is finer and the river is bordered by fertile farm land, which is readily irrigated by water from the mountain streams and the Po. It is necessary to build dikes along many of the streams to prevent their overflowing the plain. Thus confined to their channels, the rivers are obliged to deposit sediment in their beds. In consequence of this, the surface of the Po is now well above the level of the surrounding country.

Summary. — *The wash of rock fragments from inclosing mountains sometimes deeply fills valleys, especially in arid lands.*

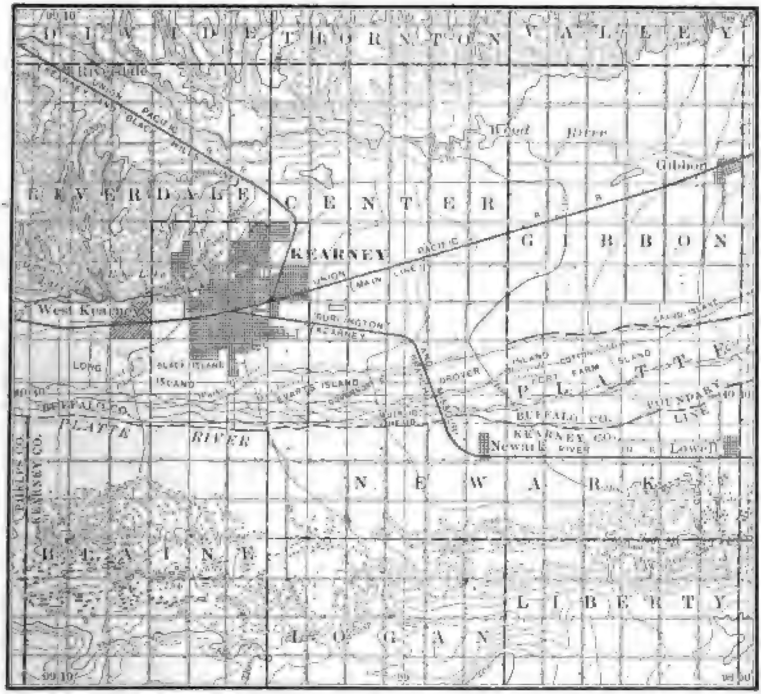


Fig. 112. — The branching course of the Platte River in Nebraska, which has so much sediment that it is aggrading its bed, and doing it so rapidly that it flows not in a channel, but in a braided series of branches. (Part of Kearney, Neb., Topographic Sheet, U. S. Geological Survey.)

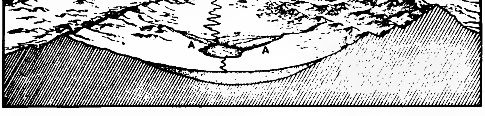


Fig. 113. — To illustrate valley filling, as in the California valley.

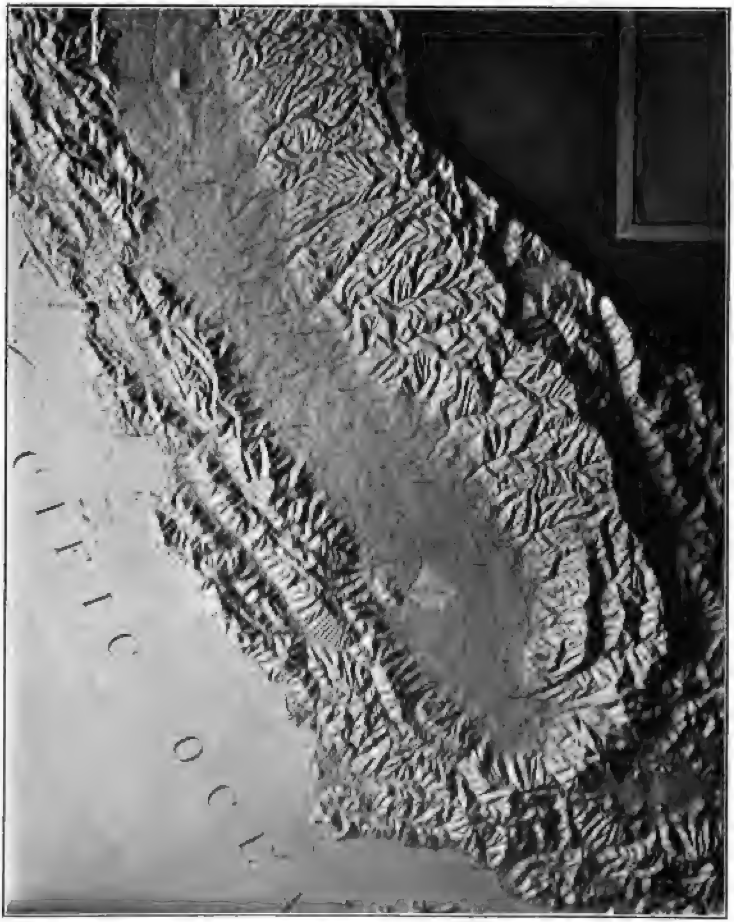


FIG. 114. — Valley of California. The flat-bottomed valley is deeply filled with sediment washed in from the bordering mountains. Notice Tulare Lake formed by the low alluvial fan of King River. (From model made by N. F. Drake.)

Topical Outline, Questions, and Suggestions.

Topical Outline.—30. **Supply of Water.**—Underground supply; run off; variation in run off; regulation of river volume.

31. **Rain Sculpturing.**—Conditions favoring; results; Bad Lands.

32. **The Rock Load of Rivers.**—Dissolved mineral; rock fragments; variation in size; tools of erosion; great load carried.

33. **Erosive Work of Rivers.**—Nature of work; corrosion; corrasion; lateral cutting; causes for variation in rate; influence of sediment; degrading; aggrading; influence of joint planes; of ice.

34. **Waterfalls.**—Relation to rock; pot-hole work; water power.

35. **Young Stream Valleys.**—(*a*) Initial drainage on a plain: lakes; divides; tributaries; consequent course. (*b*) Early stages of development: steep-sided valley; waterfalls; broadening of valley; base level; removal of lakes; narrowing of divides. (*c*) Meaning of youth: characteristics; illustration; age in years; comparison with plants.

36. **The Grade of a Stream.**—Nature of grade; degrading streams; aggrading streams.

37. **Mature Valleys.**—Broadening of valleys; absence of lakes; of waterfalls; development of tributaries; of divides; of floodplains.

38. **Old Valleys.**—Peneplains; reasons for general absence.

39. **Importance of Valley Form.**—Young valleys; mature valleys.

40. **Springs and Underground Channels.**—(*a*) Springs: causes; situation; mineral springs. (*b*) Caverns: cause; underground drainage; outlets; stalactites; stalagmites; columns; sink holes; natural bridges.

41. **River Floodplains.**—Where found; the bluffs; cause of floodplains; fitness for agriculture; natural levees; levees; meanders; ox-bow cut-offs.

42. **River Terraces.**—Cause; form; frequency in soft deposits; value.

43. **Deltas.**—Cause; name; origin of form; distributaries; surface slope; favoring and opposing conditions; settlement; dangers.

44. **Alluvial Fans.**—Cause; size; form; building of the fan; location; formation of lakes; agriculture; shifting of stream.

45. **The Filling of Valleys.**—Favoring conditions; valley of California; valley of the Po,—filling, farm land, effect of dikes.

Questions.—30. In what ways are rivers supplied with water? What causes variation in run off? What serve to regulate the volume?

31. What are Bad Lands? Where are they most common? Why?

32. In what two forms is river load carried? How is each supplied? What is the effect of differences in current? What effect have the rock fragments on erosion? Give an illustration of river load.

33. By what two means are rivers wearing at their channels? What effect have they on their banks? State the several causes which influence the rate of river erosion. Define degrading and aggrading rivers.

34. What is the most common cause for waterfalls? Give an illustration. What causes pot holes? Of what use are falls and rapids?

35. What are the characteristics of new drainage on a plain? What changes occur in valley form, lakes, tributaries, and divides? What is a consequent course? Base level? State the characteristics of young valleys. What does the term *youth* mean?

36. What is grade, and what causes it to vary?

37. What changes in valley form occur after a stream has reached grade? What about lakes and falls? What changes occur in tributaries? What influence does this have on sediment?

38. What is a peneplain? Why are they so uncommon?

39. What influence have young valleys on man? Mature valleys?

40. State the causes for springs. What causes caverns? What deposits are made in them? What are sink holes? Natural bridges?

41. What causes floodplains? Why are they level? Of what importance are floodplains? What is the natural levee? What causes meanders? Ox-bow cut-offs?

42. What is the cause of terraces? Of what value are they?

43. What is the cause of deltas? Why so named? What gives the delta form? What conditions favor and what oppose their formation? What about the population of deltas and floodplains?

44. What are the characteristics and causes of alluvial fans? Where do they occur? Of what importance are they?

45. In what manner is the valley of California being filled? The Po valley? Of what importance is this valley filling?

SUGGESTIONS. — (1) What is the source of the water of your nearest stream? Does it vary? Why? If there were no underground supply would it in any way affect you? (2) Where does the water run off most rapidly, on a road, a grass-covered lawn, or in the woods? Answer from your own observations. Why does it run off faster in one place than in another? From which place is most sediment washed to the streams? (3) Make a little channel in the ground and pour water into it, varying the amount from a small flow to a flood. Now make a small pond, say, five feet long, with the little channel for its outlet. Pour the same amount of water into the pond that you did into the channel. Does the outflow channel show the same variation in volume? (4) Weigh a stone in the air with a spring balance. Weigh the same stone submerged in water on the end of a string. What does the result show? (5) Make a little trough of rough wood and let water run through it from a faucet. On the bottom of the trough place small pebbles, sand, and clay. Vary the velocity of the water to see what happens. Record your results. (6) Has the stream nearest you a rapid or slow flow? What

is the size of the rock fragments that it carries at ordinary times? At times of flood? Why the difference? Is the material at the bottom coarser than that suspended in the current? Where do the rock fragments come from? (7) Are the streams near your home aggrading or degrading? If degrading, are they aggrading in some parts? Why? What differences in work do you see from time to time? Does rock structure influence the work? Observe the stream in winter and spring to see if ice helps. Do you know of any places where they are cutting against the banks? (8) Are there any falls or rapids? What causes them? Are there any pot holes? Find what is in the bottom. What does this show? (9) Look for evidences of rain sculpturing on roads, in plowed fields, or under gutters. Place some flat pebbles on some clay and wash it away with a sprinkling pot. Are any columns formed? (10) Has the stream nearest you reached grade? Is the valley young or mature? Study and describe the valley, — its form, tributaries, divides, and falls and lakes (if present). What influence has the valley on roads, railways, and industries? (11) Has your river a floodplain? Is the plain ever flooded? If so, go after the next flood to see if deposits of sediment have been made. Does the river meander? Have there been any changes in the meanders? (12) Terraces are common in sections where streams are cutting away glacial deposits. Are there any near your home? If so, study and describe them. (13) If there is a pond or lake near by, see if there are not deltas opposite the mouths of both the large and small streams. If so, report on what you observe concerning their form and the material of which they are made. (14) Are there any alluvial fans? Look for them in mud puddles at the base of a clay cliff, for example in a railway cut. You can make one by building a pile of clay with steep slope and washing the clay down to the base with a sprinkling pot.

Reference Books. — Russell, *Rivers of North America*, Putnam's Sons, New York, 1898, $2.00; Tarr, *Physical Geography of New York State*, Chapter V, Macmillan Co., New York, 1902, $3.50; Hovey, *Celebrated American Caverns*, Robert Clarke Co., Cincinnati, 1896, $2.00; Shaler, *Aspects of the Earth*, Chapters III and IV, Scribner's Sons, New York, 1900, $2.50; Huxley, *Physiography*, Macmillan Co., New York, 1891, $1.80. See also Chapter XVI of this book.

CHAPTER V.

PLAINS, PLATEAUS, AND DESERTS.

PLAINS.

46. Continental Shelf Plains. — Off the coast of eastern North America there is a sea-bottom plain sloping out into deep water (Fig. 116). It attains a width of 50 or 100 miles, and its outer edge is covered by about 600 feet of water. The surface is a level expanse of sand near the coast, and of mud farther out. The plain is made of layer upon layer of sediment washed from the land, and the waves and currents are constantly adding to it. Other continents are bordered by similar sea-bottom plains, or continental shelves (Fig. 316).

Should this sea bottom be raised 600 feet, a broad strip of plain would be added to the American continent. It would slope at the rate of a few feet a mile, and the rain that fell upon it would find such difficulty in passing off that much of the surface would be swampy.

Summary. — *Continents are bordered by sea-bottom plains, or continental shelves, made of sediment from the land.*

47. Coastal Plains. — Uplifts have actually added such plains to the land (Figs. 122, 123). Some are narrow strips at the base of mountains, as in western South America (Fig. 117), where the land is still rising; others are many miles wide, like the plain that skirts the coast south of New York. Because they border the coast they are called *coastal plains*.

The coastal plain of the Atlantic and Gulf coasts extends from New Jersey to the Rio Grande, and includes the peninsula of Florida. Wells bored into it pass through hundreds of feet of gravel, sand, and clay, often finding water in the

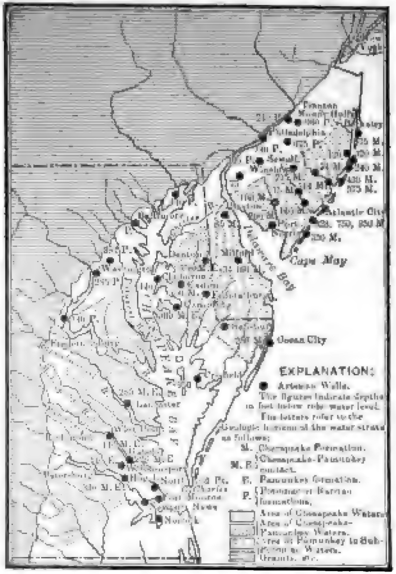


FIG. 115. — Location of artesian wells on the coastal plain from New Jersey to Virginia.

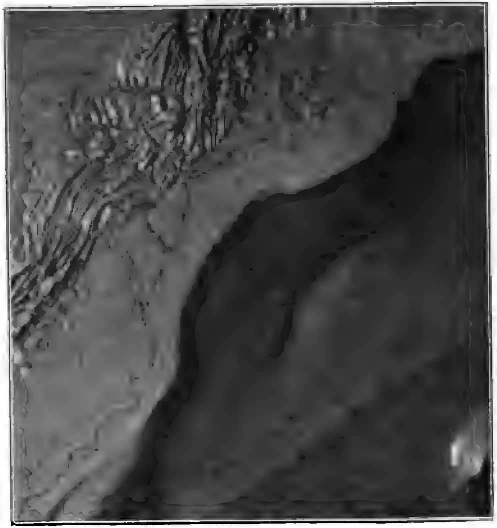


FIG. 116. — Continental shelf off eastern United States. (Vertical scale greatly exaggerated.)

Fig. 117. — Narrow coastal plain of western South America, a few miles wide.

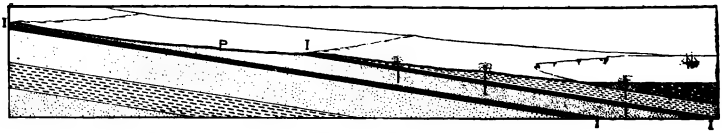


Fig. 118. — Diagram to illustrate the cause for artesian wells on a coastal plain. Water passes down the porous layer *P*, and is prevented from rising or going deeper by the impervious layers *I*, *I*. When a well is bored down to the porous layer the water rises to the surface because it has entered higher than the outlet of the well, and is under pressure of the water in the porous layer, which, therefore, forces it out. Such a well may even be bored on a sand bar in the sea, finding water beneath the impervious layer.

Fig. 119. — The Florida plain along the St. John River.

Fig. 120. — A view of the palmettoes on the Florida plain.

Fig. 121.—The coastal plain along the Potomac River. Notice how level it is; how branching the bay is; how swampy the lower courses of the rivers are; how flat-topped the divides are; and how the roads follow them. (The lines are contours.) (From Wicomico, Md., Sheet, U. S. Geological Survey.)

porous, sandy layers. Where the water rises to the surface, it is called an *artesian well* (Fig. 118). There are hundreds of such wells along the Atlantic coast (Fig. 115), and many cities, such as Galveston, obtain drinking water from them. Artesian water is pure and free from the germs that abound in surface drainage.

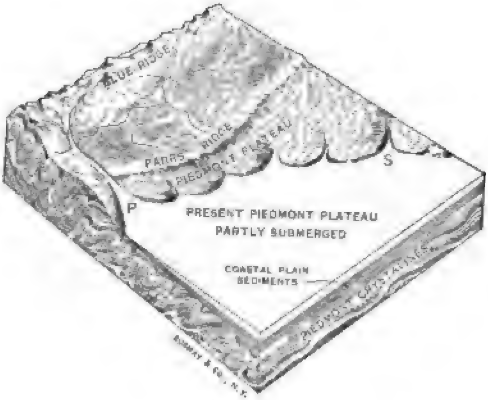


Fig. 122. — A sea-bottom plain being formed by the deposit of sediment on a submerged old land.

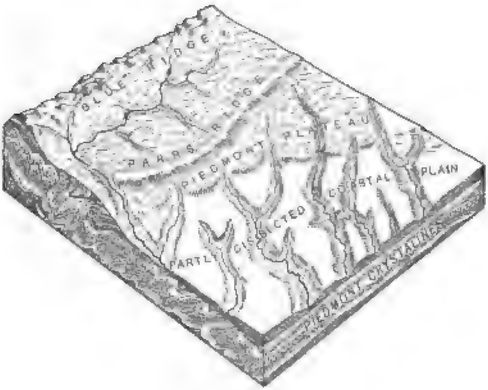


Fig. 123. — Same as Fig. 122, elevated to form a coastal plain. Rivers from the old land are extended out upon the coastal plain. This is the condition of the coastal plain southward from New York.

Much of the coastal plain is so sandy that it is poorly adapted to agriculture, and is still occupied by an open pine forest in which cattle roam, feeding on the scattered grass. The forest supplies valuable lumber, turpentine, tar, and other products. The higher and less sandy tracts are favorable to agriculture, producing fruit, grain, etc., in Maryland, Delaware, and other

states, and cotton, corn, and other products in the South. Along the coast and near the rivers the land is swampy, being useful in the South for rice culture.

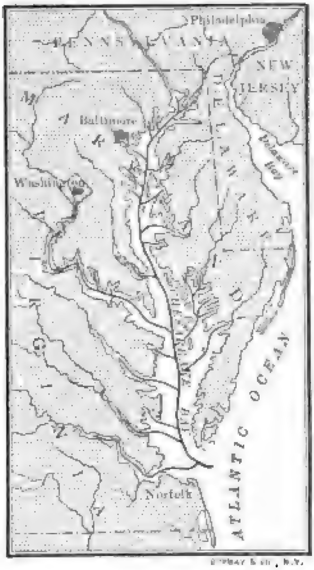


FIG. 124. — The branching Chesapeake. The lines show the probable position of the rivers that formed this branching, submerged valley.

A slight sinking of this coastal plain has admitted the sea into the valleys, transforming their mouths to shallow bays (Figs. 121, 124), the seats of oyster and fishing industries. Some of the deeper bays have good harbors, though a fringe of sand bars partly cuts off the entrance to many. The shallower bays and tide-water rivers are navigable by small craft, thus opening up large areas of country to water transportation. This has helped greatly in carrying cotton and other products to the seaports for shipment. Chesapeake Bay, with its many branches, is the largest of the coastal plain bays.

For the most part the rivers of the coastal plain are sluggish, and, in some places, the slope of the plain is so gentle that water does not run off. This causes swamps, as in parts of Florida (Figs. 78, 79, 119) and the Dismal Swamp (Fig. 307). In Texas, south of Houston, the divides are so flat and swampy that there is no agriculture, and not even cattle can find support. The surface of the Florida plain is so young, and the streams have so little sediment, that the shallow lakes in depressions of the old sea bottom have not yet been filled. Where the streams have cut into this coastal plain they occupy shallow, steep-sided valleys, with broad, flat-topped divides (Fig. 121), along whose level surface the roads run.

Where streams pass from the older land to the coastal plain (Fig. 123), their slopes increase and their courses are interrupted by rapids and falls. The explanation of this fact is that the rivers have cut faster in the soft clays and sands of the plain than in the harder rocks of the old land. For this reason the boundary between the old land and the plain is called the *Fall Line* (Fig. 125). It has had a very important influence on settlement. Even in the days of the Indians, village sites on the rivers were located along this line, — the highest points to which canoes could go from the seaward side, and where portages were necessary to pass higher upstream. White men have located cities on these same spots, the farthest points to which boats from the sea can pass inland. Along the Fall Line are located Trenton, Philadelphia, Baltimore, Washington, Richmond, Raleigh, Columbia, and Augusta.

FIG. 125.—The Fall Line. Coastal plain dotted; cities printed in heavy type are located along the Fall Line.

Summary. — *Upraised sea bottoms form coastal plains skirting the coasts of continents. There is a well-defined one from New Jersey to Mexico, much of whose level surface is too sandy or swampy for agriculture, while in Florida there are many lakes still occupying the original depressions. A slight sinking has admitted the sea into the river mouths, transforming them to shallow bays. Where streams descend from the old land to the plain there is a line of rapids and falls, called the Fall Line.*

48. The Russian and Siberian Plains. — This, the greatest expanse of plains on any continent (Fig. 21), covers an area far greater than the entire United States. These plains extend from the Caspian region to the Arctic, including a large part of northern Asia and most of Russia, with a

western branch reaching to Holland. They are made of layers of sand, gravel, and clay, washed from the mountains of Asia and Europe into a sea which has been destroyed by uplift. The uplift of this sea-bottom plain has been so recent that the streams are young: there are many swamps; shallow lakes are yet unfilled; and the divides are flat-topped.

In the North there is barren *tundra*, inhabited by scattered tribes (Fig. 126) who use the reindeer as a domestic animal (Fig. 546). The soil, frozen to great depth, thaws in summer only at the surface, making the land a vast swamp; in winter the tundra is a bleak, frozen, snow-covered desert. Toward the south it grades into the forest region which is now being cleared and opened to agriculture as a result of the building of the Siberian railway. This forest section is destined to become one of the great farming regions of the world. On its southern side the forest belt grades into the open, grass-covered *steppes* (p. 285), a region too arid for farming, and, therefore, occupied by a nomadic, pastoral people.

Summary. — *Vast plains, caused by recent uplift of an ancient sea bottom, occupy a large part of northern Asia and Europe. There is barren, frozen tundra in the north, barren, arid steppe land in the south, and forest and farm land between.*

49. Plains and Prairies of Central United States. — In ancient geological times a sea bottom between the mountains of eastern and western North America was also raised above sea level. From time to time it has been reëlevated, and numerous additions have been made to its southern margin. Denudation has also been at work, lowering and sculpturing its surface, so that in places it is hilly. It forms one of the largest areas of plains in the world (Fig. 21).

Near the Appalachian Mountains the plains reach an elevation of 2000 to 3000 feet; near the Rocky Mountains they rise from 5000 to 6000 feet above sea level. From these higher portions, really plateaus, the surface slopes toward the Mississippi, making a broad valley which that river follows, receiving long tributaries down the slopes from either side.

FIG. 127. — The Great Plains. Notice how sparse the vegetation is in this arid region.

FIG. 126. — A Laplander on the tundra.

Fig. 128. — Cattle on the Great Plains.

Fig. 129. — The great plains in Montana, near the base of the Crazy Mountains.

The plains west of the Mississippi are called the *Great Plains* (Figs. 127–129). In the eastern part they have rainfall enough for agriculture; but west of the 100th meridian they are suited only to grazing, though here and there rivers and artesian wells supply water for irrigation. Where the rainfall is light there is timber only along the streams. In early days, when Indians occupied them, crossing these vast plains was a difficult and dangerous undertaking.

East of the Mississippi are large areas of plain, called *prairies*, which, when discovered, were also free from forest. In some cases the treeless condition was due to fires, set by Indians in their buffalo hunts. In others the fine-grained soil seems to have been unfavorable to tree growth, but favorable to a luxuriant growth of prairie grass. These fertile, treeless prairies helped greatly in the settlement of the Middle West. A crop could be raised the first year, for there was no laborious work of clearing land for farming; and, when this was found out, settlers came rapidly and prospered.

Plains are not usually great mineral-producing regions, but are especially suited to agriculture when the climate is moist, and to grazing when arid. Yet, in the plains of central United States, beds of sandstone and limestone furnish abundant building stone; layers of salt are found; deposits of iron, lead, and zinc occur; and there are vast quantities of natural gas, petroleum, and coal. Where coal is present, busy manufacturing cities spring up, especially if agriculture flourishes, supplying materials for manufacture and a market for manufactured products. These conditions all exist on the plains of central United States.

Each of the continents has plains similar to those already described. The great plains of the Amazon, of Argentina, and of Venezuela are instances. A very large part of the land surface consists of plains (Fig. 21) that at one period or another have been raised from the sea.

Summary. —*The ancient and much worn plains of central United States slope from the mountains on each side, forming the great Mississippi valley. In the West the Great Plains are treeless, because arid; in the East, though the climate is moist, large areas, called prairies, were treeless because of the effect of fires and the compact soil. These plains, adapted to agriculture where humid, and grazing where arid, also contain mineral wealth, and, in the humid portion, have become a prosperous and busy manufacturing region.*

50. Lake Plains. — Sediment deposited in a lake levels its bottom. If the Caspian Sea or Lake Erie could be drained, their sites would become broad plains. There are places from which lakes have disappeared. Extinct lakes of this sort were formed by a great ice dam across north-flowing streams when the glacier was melting from North America (p. 149).

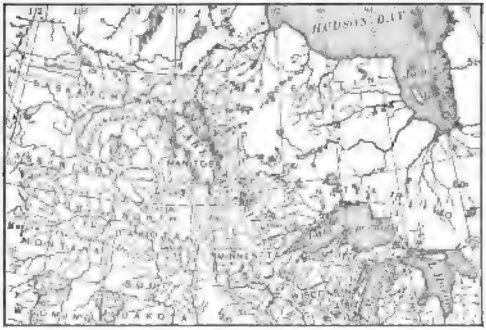


Fig. 130. — Extent of the extinct glacial Lake Agassiz, which occupied the valley of the Red River of the North.

An enormous lake of this kind, glacial Lake Agassiz (Fig. 130), larger than all the Great Lakes combined, existed in the valley of the Red River of the North. The fine-grained sediment that was deposited on the bottom of this extinct lake has made a fertile plain (Figs. 131, 132), one of the most famous wheat regions of the world. Its surface is so smooth that, after a rain, water stands on the ground in sheets.

A large lake also once existed in the Great Basin, round Great Salt Lake. When the climate became arid this lake was diminished by evaporation, leaving only small remnants, of which Great Salt Lake is the largest. These remnants occupy shallow depressions in the level lake-bottom plain (Figs. 133, 150, 301).

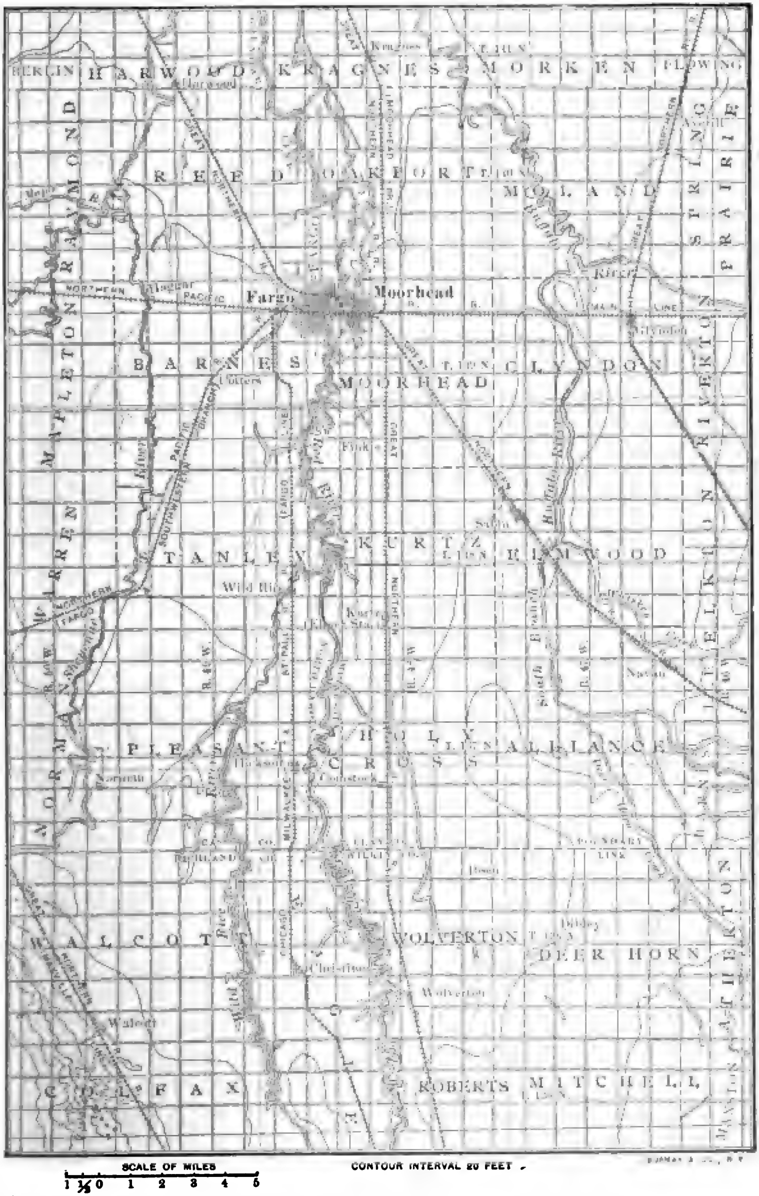


Fig. 131.—The lake-bottom plain of the valley of the Red River of the North. Notice how very level it is (see also Fig. 132). (Fargo Sheet, U. S. Geological Survey.)

Fig. 132. — Wheat fields on the Red River valley plains (Fig. 131). These plains are almost as level as the sea.

Fig. 133. — Salt Lake City, on the plain formed in the bottom of ancient Lake Bonneville (Fig. 301).

There are a number of other classes of plains. Some of these are described in the chapters on Glaciers (p. 149) and Lakes (p. 165). Others, formed by rivers, have already been described, — floodplains (p. 61), delta plains (p. 64), alluvial fan plains (p. 66), and filled valley plains (p. 67).

Summary. — *On lake bottoms sediment makes plains which may become dry land by the disappearance of the lakes, as in the valley of the Red River of the North, and the Great Basin.*

51. Life History of a Plain. — A *young plain* (p. 54) has a level surface, poorly defined and perhaps swampy divides, and

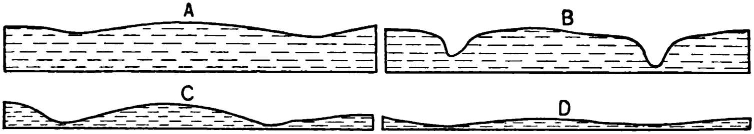


Fig. 134. — **To illustrate the life history of a plain in uniform rock (*A*), through youth (*B*), to maturity (*C*), and old age (*D*).**

shallow lakes. The consequent streams at first cut steep-sided valleys, with falls where differences in rock hardness are found.

In time the lakes are filled, grade is established, falls disappear, tributaries increase in number, divides narrow up, and the valleys broaden (p. 57). Such a *mature plain* has an undulating surface, and, if high, it may be so dissected as to become a hilly land (Fig. 134). In an *old plain* the valleys are so broadened that the surface again becomes nearly level.

The rock layers of a plain usually lie in sheets, gently inclined in the direction given them by uplift of the land (Fig. 118). As the surface of the plain is slowly worn down, durable layers, since they resist denudation better than weak ones, are left as uplands, possibly only a few feet, perhaps scores of feet, above the lower portions of the plain. Being in sheets, the durable layers form *belts* of hilly land bounded on either side by belts of lower land, where the weaker strata lie (Fig. 135). The plain is, therefore, sculptured into bands, or belts, of different level, corresponding

to the differences in the strata. Such a land surface, found both on recent coastal plains, as in eastern United States, and on older plains, as in central United States, is known as a *belted plain.*

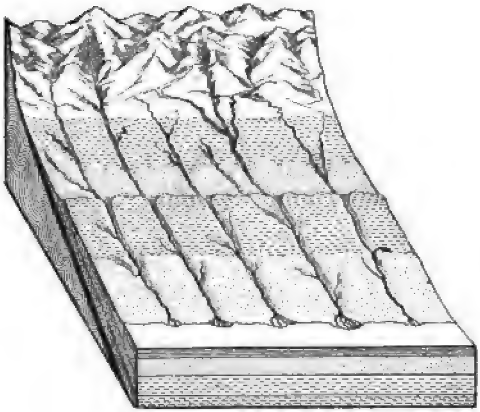


Fig. 135. — A belted coastal plain. The different symbols (dots and lines) represent different layers of rock, gently inclined toward us.

Summary. — *A young plain has a level surface and a young drainage system; a mature plain has broad valleys and a hilly surface; an old plain has a level surface again. A belted structure often results from the less rapid removal of the more resistant strata.*

PLATEAUS.

52. Nature of Plateaus. — When mountains are uplifted the country on either side is also raised, often without much folding of the strata. As the mountains rise higher the adjoining plains become more elevated, especially near the mountains and between the ranges. They may rise so high that they deserve the name plateaus, for a plateau is only an elevated plain. The plateau along the western base of the Appalachians (Fig. 146) is 2000 to 3000 feet above sea level; at the eastern base of the Rocky Mts. (Fig. 129), from 5000 to 6000 feet; between the Rockies and the Sierra Nevada, often 7000 to 8000 feet; north of the Himalayas (Fig. 136), over 10,000 feet.

Owing to the close relation between plateaus and mountains (Fig. 136), the strata of plateaus, though mostly horizontal, are sometimes broken and tilted; in fact, there is every

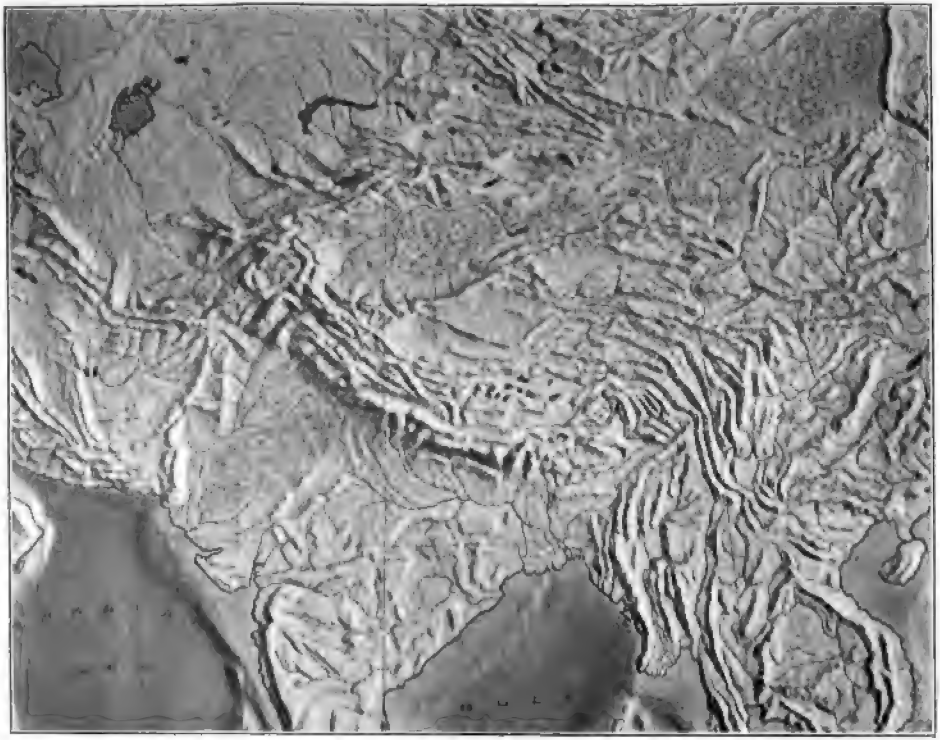


Fig. 136. — The high plateaus and mountains of central southern Asia, including the plateau of Tibet.

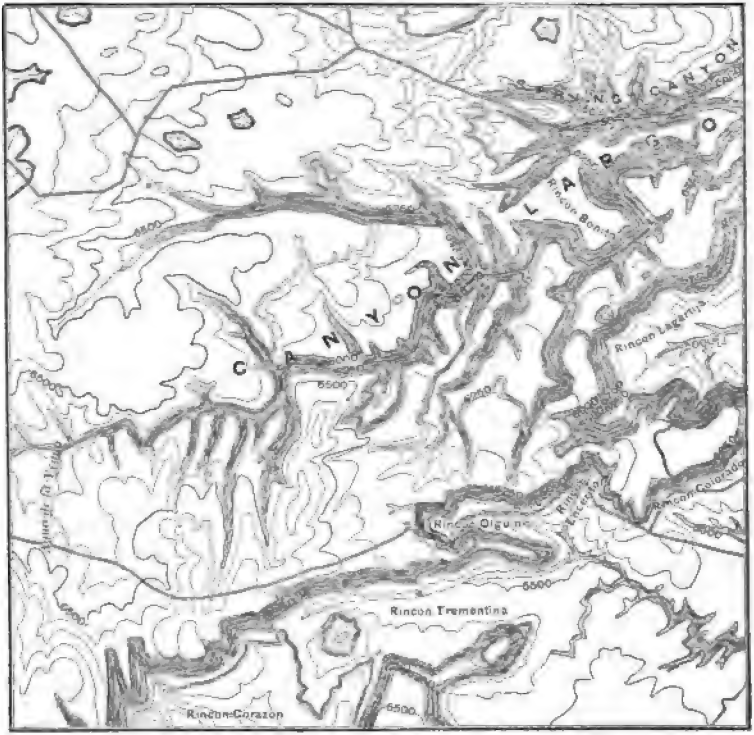


FIG. 137. — Map of a young river system on the plateau of northern New Mexico. (Part of Watrous Sheet, U. S. Geological Survey.)

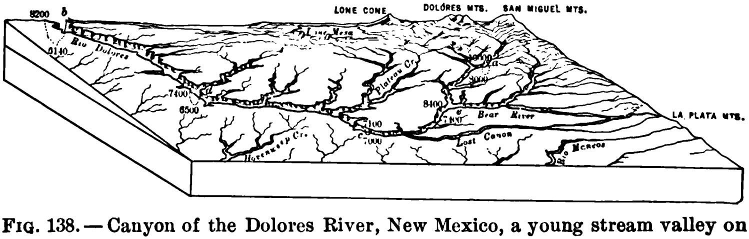


FIG. 138. — Canyon of the Dolores River, New Mexico, a young stream valley on an arid plateau.

gradation from slightly tilted plateau blocks (Fig. 155) to true mountains. Lava has often welled from the fissures, flooding large areas of country, as in the Columbia and Snake River valleys (Fig. 476).

Summary. — *Plateaus are elevated plains, raised during mountain uplift, with strata usually horizontal, though sometimes tilted.*

53. Sculpturing of Plateaus. — Rivers upon plateaus have much the same history as upon plains (p. 54); and the life history of a plateau is much the same as that of a plain (p. 79). But, being higher above base level, the streams have more work to perform, and this takes a longer time. Young streams sculpture plateaus into extremely rugged form, with flat-topped divides, and deep, steep-sided valleys, with falls and rapids. The valleys grow broader, the surface lower, and finally, in old age, the land is level again.

The sculpturing of plateaus is frequently retarded by the fact that the climate is arid and denudation therefore slow (p. 41). For this reason many arid land plateaus are still in the rugged stage of youth, even though in years they may be far older than maturely dissected plateaus of humid regions. For the same reason arid plateaus have an angular topography (Figs. 140, 148), while in moist climates denudation more commonly rounds the edges of the strata.

Summary. — *Plateaus, like plains, pass through stages of youth, maturity, and old age. But, since they are higher, the time required to lower them is longer, and the land forms produced are more rugged. The arid climate of many plateaus retards denudation and therefore prolongs youth.*

54. Canyons. — A canyon is the deep, steep-sided valley of a young plateau stream (Figs. 137, 138). Canyons are found on most plateaus, being a characteristic result of the early stages of river erosion in high plateaus. Far the best instance is the Grand Canyon of the Colorado. (Frontispiece; see also p. 322.)

For about 200 miles the Colorado River flows in a canyon, in one place 6000 feet in depth — the deepest canyon in the world. Some of the grandest scenes in nature are the views looking down into this river-made valley from the canyon edge, or looking upward from its bottom. The internal structure of the earth's crust is here revealed — thousands of feet of strata, layer on layer, appearing one beneath the other. One cannot look into this enormous cut in the earth without realizing the vast work which a river can do when time enough is allowed. Yet it is the work of a young stream still cutting down toward grade.

FIG. 139. — The Colorado Canyon from the bottom. A view showing the wreck of one of Powell's boats in his venturesome trip through the canyon.

Summary. — *Deep, steep-sided valleys of young plateau streams are called canyons. The greatest of these is the Canyon of the Colorado, over* 200 *miles long and, in one place,* 6000 *feet deep.*

55. Mesas and Buttes. — In plateaus there are many flat, table-like surfaces (Fig. 140) faced by steep slopes, often cliffs. These are *mesas*, a Spanish word meaning table. An examination of such a mesa shows that the rock on the top is hard, often lava. These table-top surfaces are due to the fact that the more durable rock layers have resisted denudation; and, since they are nearly horizontal, have held the surface up to a general level, parallel to the stratification.

Fig. 140. — Mesa Verde, Colorado. The horizontal hard stratum that protects these mesas from being worn away has a steep slope, while the softer strata beneath have a more gentle slope.

Fig. 141. — Crow Heart Butte, Wind River, Wyoming.

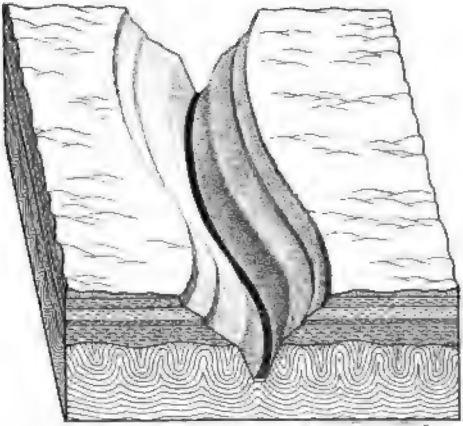


Fig. 142. — A superimposed river, reaching folded rock beneath the horizontal strata of a plateau.

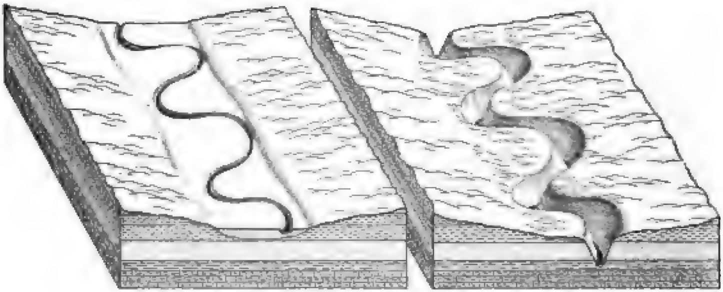


Fig. 143. — A rejuvenated river. In the left-hand figure the stream has reached grade and is swinging over a floodplain in a gently sloping, mature valley. In the right-hand figure the land has been uplifted and a young valley is sunk in the bottom of the mature valley, preserving some of the meanders that the stream had before the uplift. These may be called *entrenched meanders*.

Small detached sections of mesas, cut off by denudation, are called *buttes* (Figs. 141, 144). They, too, are capped by durable layers which have preserved them from being worn down. The presence of these flat-topped butte and mesa areas accounts for the name *tableland*, often given plateaus.

FIG. 144. — A butte on the Great Plains.

Summary. — *Flat-topped areas, called mesas if large, buttes if small, due to the resistance of horizontal beds of hard rock, are common among plateaus, giving rise to the name tableland.*

56. Superimposed and Rejuvenated Rivers. — In cutting into the strata of plains and plateaus, rivers may wear down through the horizontal layers to buried mountains (Fig. 123). Such rivers are said to be *superimposed* on the buried structure (Fig. 142). The Colorado River, for example, has discovered an old, buried mountain mass in one part of its canyon.

An uplift of the land gives a river new life, or rejuvenates it. The stream then cuts a narrow gorge in the bottom of its old valley (Fig. 143). Such a valley is *rejuvenated*, or made young again.

Summary. — *Superimposed rivers are those which cut through one set of layers to another of different position. A rejuvenated river is one made young again by any cause, as by uplift.*

57. Climate of Plateaus. — High plateaus are cold because they reach into cool upper layers of the atmosphere. On the

plateau of Mexico, for instance, the climate is tropical at the base; coffee is grown on the lower slopes; but grains are the chief crops on top. In the lower Colorado valley, in Arizona, the summer climate is almost unbearably hot, while on the plateau it is pleasantly cool. The plateau of Tibet is so high that it has a cold, disagreeable climate, even in summer.

Plateaus are often associated with mountains, which shut out the rain-bearing winds. Many plateaus are therefore arid, and some, like central Asia and parts of western United States, are true deserts.

Summary. — *Plateaus have a cooler climate than neighboring lowlands; they are often arid.*

58. Inhabitants of Moist Plateaus. — The plateau at the western base of the Appalachians (p. 80) includes the Catskill, Alleghany, and Cumberland mountains. It is dissected by valleys, often 1000 feet deep (Fig. 145), with sides too steep for cultivation, but, owing to the moist climate, clothed with forest (Fig. 146). There are no true buttes and mesas, and no real canyons; but the surface is, nevertheless, very rugged.

Much of this plateau is a wild region, with a sparse population, and with its forest areas still occupied by wild animals. It is an important source of timber. The scattered farms are poor and, south of Pennsylvania, where the rugged, timber-covered surface interferes with communication with the outer world, there are sections in which the people are very backward. Many cannot read or write; illicit distilling of whisky is one of the industries; and, in some parts, there are family feuds and lawlessness, resulting in much loss of life.

The discovery of coal has led to the opening of parts of this plateau to other occupations than lumbering and the crude farming of the backwoodsmen. In this respect the plateau of western Pennsylvania has advanced far ahead of that of West Virginia, Tennessee, and Kentucky. In New

Fig. 145. — The hilly plateau of southwestern New York. (Part of Salamanca Sheet, U. S. Geological Survey.)

FIG. 146. — The Alleghany plateau with steep, wooded slopes.

York (Fig. 145) the plateau is less rugged, and, consequently, better developed. It has, in large part, been cleared of forest, and farm lands have been developed wherever possible. Yet even here the upland farms are poor in quality.

Summary. — *Rugged, dissected plateaus in moist countries, like that west of the Appalachians, are largely forest-covered, poorly adapted to farming, and, unless influenced by the development of mineral resources, are apt to be occupied by a sparse population, little influenced by the outside world.*

59. Inhabitants of Arid Plateaus. — Because of their ruggedness, cold, and dryness, arid plateaus are sparsely settled. In the West, large areas of plateau are almost uninhabited except by ranchmen, whose cattle and sheep feed on the sparse growth of grass (Figs. 127, 128).

Because of the dryness there is little farming, except near the mountains where alluvial fans and level portions of the plateau are irrigated by water from the mountain streams. The bottoms of the canyons are rarely wide enough for farms, and it is usually impossible to lead the water out for use in irrigation.

The Indians who occupied the arid plateau of southwestern United States farmed by means of irrigation. For protection from roaming bands of more savage Indians, they often built their homes, or *pueblos*, on the buttes and mesas, which they resemble in color and form. From them they could look out over the country, and be partly protected from enemies by the steepness of the bordering cliffs. Some Indians (Fig. 148) still live in these situations. Other Indians lived in caves in the cliffs, and still others under overhanging ledges, where weather and wind had removed weaker rocks from beneath the more durable ledges. The latter are called *cliff dwellers*, the former *cave dwellers*. These habitations are no longer occupied.

Summary. — *Arid plateaus are usually sparsely settled, the leading occupation being ranching, with farming by irrigation where possible.*

DESERTS.

60. Nature of Deserts. — A desert is a region in which few forms of life can find sustenance. Thus, by reason of cold, the vast expanse of ice in Greenland is a desert; indeed, it is such a one that, in a large part of its area, *no* animal or plant can live. The term *desert* is, however, commonly applied to those lands on which there is so little rainfall that only a few especially adapted animals and plants can live. About one fifth of the land has an annual rainfall of less than ten inches and is, therefore, desert; and fully as much more is arid, having too little rain for agriculture.[1]

It is a mistake to suppose that *no* rain falls in deserts, for there is no land on the earth so desert that it does not have some rainfall. One of the driest deserts is in southern Peru, where, close by the Pacific, a period of seven years has elapsed between rains. Nor is it correct to imagine deserts as dreary wastes of sand, and monotonous expanses of plains. It is true that there is much drifting sand, and that most deserts are either plains or plateaus; but deserts also have many bare rocky slopes, and even mountains (Figs. 150–152). Where the mountains rise high enough, rain falls on their slopes, streams flow down their valleys, and forests clothe their sides.

Summary. — *Deserts are due to cold, and to lack of rain, though even the driest have some rainfall. Most deserts are plains and plateaus, with much sand, though there are also mountains and many bare, rocky slopes.*

61. Drainage of Deserts.—With so little rain there is naturally little drainage. Most of the rainfall either quickly evaporates from the surface or sinks into the soil; but a heavy rain is followed by a rapid run off, because there is little vegetation to check the flow of the water. Heavy rains, known as "*cloudbursts*," sometimes occur, especially in the

[1] For explanation of desert climates, see page 281.

mountains; and the water, running out upon more level land, causes floods, which, however, quickly subside.

Because of these sudden floods, it is dangerous to camp in a dried-up stream bed, or *arroya.* Railways crossing deserts are often damaged by these floods; crops and houses are washed away; and vast quantities of sediment are brought down. This forms alluvial fans, often very stony near the mountains.

It may be months or even years between rains, so that desert streams are typically intermittent. Those from the mountains have a more regular flow, and some have such a large and steady water supply that they are able to maintain their course entirely across a desert. Thus the Colorado River and the Nile, fed from distant mountains, flow across deserts to the sea.

Most desert streams carry so little water that they lose themselves, or wither away, a few hundred yards, or a few miles, from the base of the mountains in which they are born. Sometimes they terminate in a salt marsh, or *saline;* sometimes in an *alkali flat* (p. 169); sometimes, when there is enough water, in salt lakes. The alkali and salt are brought in small quantities, dissolved in the water, and left when it evaporates. Where salt lakes formerly existed, and on the salines and alkali flats, there are barren and desolate areas of glistening salt or alkali.

Summary. — *Most desert streams are intermittent and subject to occasional floods; but some large rivers, fed among the mountains, maintain their course across the desert. Many streams wither on the desert and end in salt lakes, salines, and alkali flats.*

62. Wind Work on Deserts. — On deserts the work of the wind (Fig. 147) is more important than that of water. Small dust whirlwinds are common on hot summer days, and even moderate winds drift the sand and dust along the surface. Violent winds raise the sand in the air, causing fierce dust storms which obscure the sky and land, and even endanger life. During such a wind the movement of the sand may entirely change the details of the land surface. The finer dust is often drifted far away, dust from the Sahara having settled in central Europe and on ships west of Africa.

It is this wind work that piles up the sand which every one associates with deserts. The sand is made of small rock fragments weathered from the cliffs (Fig. 151), and brought down by the streams. It is drifted about, and gathered into vast areas of *sand dunes*, which are so difficult to cross that, wherever possible, caravan routes carefully avoid them. The sand dune hills may reach a height of several hundred feet, though usually they are much lower.

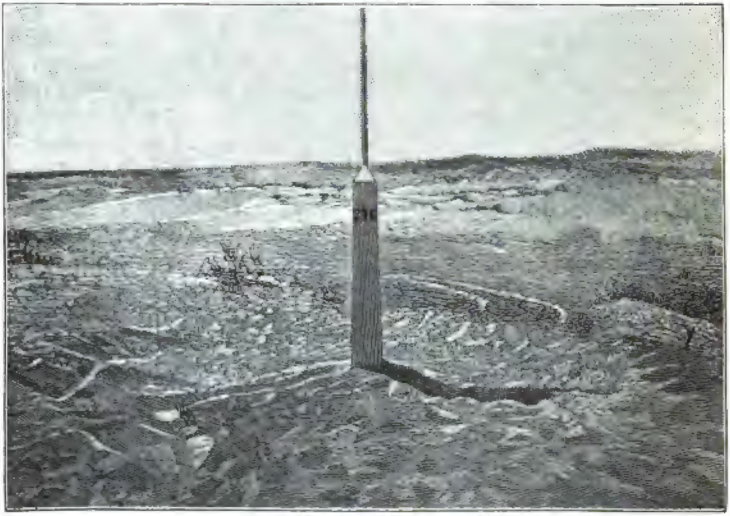


Fig. 147. – Ripple marks caused by winds blowing the sand about in southwestern United States, on the Mexican boundary.

The front is steep on the side away from the wind, and the surface is rippled with sand waves (Fig. 147), formed by movement of the sand before the wind. Sand dune hills slowly change form and position, and cities in central Asia have been buried by their advance.

Summary. — *Winds move the small rock fragments about, accumulating the sand in favorable positions, thus forming belts of sand dunes which are ever changing in form and position.*

63. Life on Deserts. — Deserts offer little incentive to human occupation. The barrenness of the country (Figs. 148–151)

Fig. 148. — The Moqui Indian pueblo on the edge of a mesa in Arizona.

Fig. 149. — Desert of Egypt at the Pyramids.

Fig. 150. — Desert near Great Salt Lake, Utah.

FIG. 151. — A view in the Sahara Desert.

FIG. 152. — Oasis of Biskra in the Sahara.

and sparseness of the population are unfavorable to the development of mineral deposits, and there is little opportunity for other industries. The rainfall is too light for agriculture without irrigation, and only a few parts have a water supply for irrigation. Areas which have water are called *oases* (Fig. 152); these are usually either scattered springs in the desert, or else places where streams descend from mountain canyons and flow out upon alluvial fans. A large stream, like the Nile or Euphrates, causes a large oasis which may support an enormous agricultural population.

A few scattered people find life possible in all the desert lands. In the Old World the desert people (Fig. 526) are *nomads*, or wanderers, who move with their herds from oasis to oasis, to give the animals a chance to feed on the sparse desert vegetation. Such a life of danger and privation develops a hardy, warlike people, with love of freedom and a contempt for the monotonous settled life of the farmer. These people, having learned how to use the camel (Fig. 519), "the ship of the desert," for carrying their burdens, have long been traders and caravan leaders across the deserts. For centuries the chief means of communication between the east and west of the Old World was by caravan. Many of the Bible descriptions refer to desert life, for Palestine is surrounded by desert and is on caravan routes.

Summary. — *Except on the oases, deserts are unfavorable to settlement, being occupied, in the Old World, by a scattered nomadic population, engaged in herding and in caravan trade by use of the camel.*

Topical Outline, Questions, and Suggestions.

Topical Outline. — 46. **Continental Shelf Plains.** — Off North American coast, — width, depth, origin; result if uplifted.

47. **Coastal Plains.** — (*a*) Origin and instances. (*b*) Atlantic coastal plain: extent; structure; artesian wells. (*c*) Agriculture: sandy soil; higher lands; swamp lands. (*d*) Coast line: effect of sinking; fishing; sand bars; navigation. (*e*) Rivers: swamps; lakes; young valleys. (*f*) Fall Line: cause; Indian settlements; location of cities.

48. **The Russian and Siberian Plains.** — Extent; origin; condition of drainage; the tundra; the forest belt; the steppes.

49. **Plains and Prairies of Central United States.** — (*a*) General features: origin; later changes; elevation; slopes; influence on Mississippi. (*b*) Great Plains: climate; grazing; agriculture; timber. (*c*) Prairies: cause; influence on settlement. (*d*) Mineral deposits: kinds; influence on manufacturing. (*e*) Other great plains.

50. **Lake Plains.** — Lake bottoms; drained lake bottoms; Red River valley plains; evaporated lake bottom plains; other classes of plains.

51. **Life History of a Plain.** — Young plain; mature plain; old plain; belted coastal plains, — strata, denudation, result.

52. **Nature of Plateaus.** — Association with mountains; relationship to plains; elevation of certain plateaus; tilted plateau blocks; lava floods.

53. **Sculpturing of Plateaus.** — Life history; effect of arid climates.

54. **Canyons.** — Definition; occurrence; Colorado Canyon.

55. **Mesas and Buttes.** — Mesas; buttes; tablelands.

56. **Superimposed and Rejuvenated Rivers.** — (*a*) Superimposed: meaning; example. (*b*) Rejuvenated.

57. **Climate of Plateaus.** — Coolness; illustrations; arid climate.

58. **Inhabitants of Moist Plateaus.** — Surface features of plateau west of the Appalachians; inhabitants; occupations; coal mining; New York.

59. **Inhabitants of Arid Plateaus.** — Climate; ranching; irrigation; Indian pueblos; cliff dwellers; cave dwellers.

60. **Nature of Deserts.** — Two causes; extent; rainfall; surface features.

61. **Drainage of Deserts.** — Rainfall; run off; "cloud-bursts"; arroyas; effects of floods; intermittent streams; large streams fed from mountains; withered streams; salines; alkali flats; salt lakes; cause.

62. **Wind Work on Deserts.** — Importance; sand storms; source of sand; sand dunes; change in position.

63. **Life on Deserts.** — Mineral; farming; oases; nomads; camel.

Questions. — 46. What are the conditions on the sea bottom off the North American coast? What would result if it were elevated?

47. Where are coastal plains found? Why? Why is artesian water found in them? What industries are developed on the Atlantic coastal plain? What is the nature of the coast line? Why? What are the evidences of youth? What are the cause and effects of the Fall Line?

48. What is the extent of the Russian and Siberian plains? What is their origin? What proof is there of youth? What are the conditions in the northern, central, and southern portions?

49. What is the general condition of the plains of central United States? What are the conditions on the Great Plains? Why are the prairies treeless? What effect has this condition had? Account for the development of the central plains region. Where else are similar plains found?

50. What has caused the plains of the valley of the Red River of the North? Those near Great Salt Lake? What other kinds of plains are there?

51. State the life history of a plain. Explain belted plains.

52. How are plateaus related to mountains? How do they differ from plains? What is the condition of the rock strata?

53. How does the life history of plateaus resemble and differ from that of plains? What effect has an arid climate on sculpturing?

54. What is a canyon? Describe the Colorado canyon.

55. Explain mesas. Buttes. Account for the name tableland.

56. What are superimposed valleys? What are rejuvenated valleys?

57. How do plateaus affect temperature? Give illustrations. Why are plateaus often arid?

58. What is the condition of the plateau west of the Appalachians? What effect has this on the people? What differences are there from Tennessee to New York? Why?

59. Why are arid plateaus sparsely inhabited? What are the industries? How did the Indians of the Southwest formerly live?

60. State the causes for deserts. What about the rainfall? The surface features?

61 Describe the conditions of drainage in deserts. What is the cause of salt and alkali deposits?

62. Describe wind work in deserts. Describe and explain desert sand dunes.

63. What are the industries of deserts? What are nomads? How do they live? Of what importance is the camel?

SUGGESTIONS. — (1) Make a coastal plain. In a shallow dish make an irregular land surface of clay. Have one portion hilly to represent land, the other part low. Fill the lower portion with water. With a sprinkling pot carefully wash some of the land into the depression, then drain off the water with a siphon. Notice the marginal plain that is built off the land. It is a fair miniature of a coastal plain. Is it perfectly level? What irregularities are there? Why? (2) In the same dish mold a basin of clay, and drop pebbles on the bottom to represent hills. Partly fill with water. Sprinkle clay into the water, and, after it has settled, draw off the water. If clay enough has been added the bottom will be level, quite like a drained lake. What is the nature of this bottom? How does it compare with those described in the text? The conditions which existed in the Great Salt Lake region can be imitated by allowing the water to evaporate, instead of drawing it off. The condition in the Red River valley can be imitated by making one side of the basin of packed snow or ice and allowing it to melt, thus draining the lake.

(3) Make a basin similar to the above, but use salt water (dissolving salt in the water before pouring it in). Then allow it to evaporate. What is the result? This is similar to the conditions which have caused many beds of salt, for example, those of New York, Michigan, Kansas, and the Far West. (4) To make an artesian well. On a gently inclined board (say at an angle of 10°) place a layer of sand and pebbles, two inches thick; cover with a piece of thin cotton cloth, or cheese cloth; and then place on this a layer of clay four inches thick. Extend the clay down over the lower edge and the two sides of the pebble layer, making it so tight that water will not seep through easily. Pour water in at the upper edge of the pebble layer. Now, near the lower end of the board, insert a glass tube six inches long down to the pebble layer (it will be well to leave a small hole in the cloth for this purpose). The water should flow out of the tube as an artesian well does. (5) Make a small plain of clay, sloping in one direction, and slowly sprinkle it with a spray of water. Watch carefully and describe every stage in the wearing away of the plain. (6) Make a much higher plain, to represent a plateau, and note the difference between the wearing away of the two. If a very thin layer is made with a little plaster of paris in it (not too firmly cemented), buttes and mesas may be made by sprinkling. (7) Map studies are suggested in Appendix J.

Reference Books. — TARR, *Physical Geography of New York State*, Chap. III, Macmillan Co., New York, 1902, $3.50; CHAMBERLIN, *Artesian Wells*, 5th Annual U. S. Geological Survey, p. 131; SALISBURY, *The Physical Geography of New Jersey*, New Jersey Geological Survey, Trenton, N.J., 1895; ABBE, *Physiography of Maryland*, Vol. I, Part II, Maryland Weather Service, Baltimore, Md., 1899; CAMPBELL and MENDENHALL, *West Virginia Plateau*, 17th Annual U. S. Geological Survey, p. 480; POWELL, *Exploration of the Colorado River of the West*, Washington, 1875 (out of print; second-hand stores); POWELL, *Canyons of the Colorado*, Flood and Vincent, Meadville, Pa., 1895, $10.00; DUTTON, *Colorado Canyon*, 2d Annual U. S. Geological Survey, p. 49; also Monograph II, U. S. Geological Survey, Washington, D. C., $10.00.

Fig. 153. — A view of an Alpine range with many peaks and ridges. Lake Lucerne is in the foreground. The lower slopes are cleared and cultivated; the higher peaks and valleys, snow-covered; the intermediate slopes, forested.

FIG. 154.—A ridge in Colorado, showing the inclined hard strata extending almost vertically into the earth. This is an arid region, and therefore the vegetation is sparse. A cactus bush is seen in the lower left-hand corner, and Spanish bayonet plants farther to the right.

CHAPTER VI.

MOUNTAINS.

64. Introductory. — Mountains contrast strikingly with plains, but resemble dissected plateaus in irregularity of form. The ruggedness and coldness of lofty mountains make them barriers rather than attractive homes. Mineral wealth often induces men to live among mountains, and, in summer, people are attracted to them by the cool climate and beautiful scenery. But, not being suited to extensive agriculture, mountains are never densely settled.

These and other facts furnish reasons why mountains are worthy of study. There are many questions of interest which such a study will answer. Why, for example, are the Alps so high and rugged, the Appalachians so low and ridge-like, and the New England mountains so low and hilly? Why do rivers sometimes cross mountains in narrow gaps while other mountain valleys are broad and flat-bottomed? The following pages answer some of these questions.

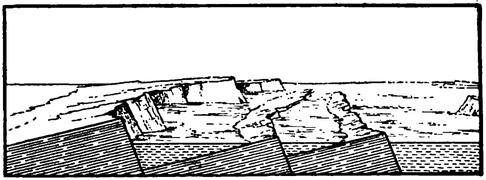


FIG. 155. — Fault block mountains.

65. The Mountain Rocks. — Unlike those of plains and plateaus, the strata of mountains are almost never horizontal. All kinds of folds and faults (p. 37) are found. Some mountains, like many in the Great Basin, are simply faulted and tilted blocks of strata, with the layers inclined in a single direction (Fig. 155). Others, like the

Jura in Switzerland, consist of strata folded into regular anticlines and synclines (Fig. 168). Still others, like the Alps, are very complexly folded and faulted (Fig. 156). The strata of the Appalachians were originally horizontal,

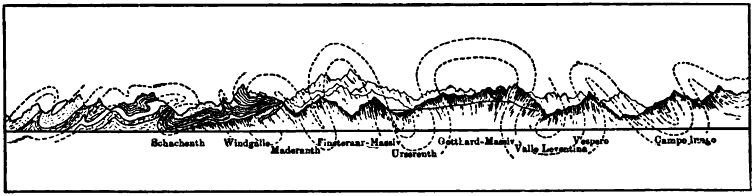


FIG. 156. — Complex folding of the Alps. The dotted lines extend the layers upward, as they would extend if nothing had been removed.

but are now complexly folded. If they could be straightened out to their original condition, they would occupy fully six times as much area as now. That is to say, 120 miles of rock strata have, by folding, been crowded into twenty miles of mountain.

Such complex folding often so alters, or metamorphoses, the rocks that it is very difficult to tell their original condition (p. 34). Igneous rocks often cut across the mountain strata (Fig. 34), and, therefore, one may in a short distance find many kinds of rock — granite, gneiss, sandstone, limestone, etc., — occupying many different positions. This complexity gives denudation an opportunity to sculpture mountains into many irregular land forms that are not possible on plains and plateaus.

Summary. — *Mountain rocks are inclined at various angles by folding and faulting, and they are also very complex in kind. In these respects mountains contrast strikingly with plains and plateaus.*

66. Names applied to Parts of Mountains. — A mountain *system* is a series of mountain folds, raised by the same uplift and forming a single group. A mountain system consists of minor portions, or *ranges* (Fig. 153). A group of mountain systems is

FIG. 157. — The Matterhorn, a steep and lofty peak in the Alps, rising above the surrounding mountains. From this region of high mountains a number of glaciers descend through the valleys, some of which are seen in the picture.

FIG. 158. — A snow-covered pass above the timber line in the Rocky Mountains of Colorado.

called a *cordillera.* For example, the cordillera of western United States includes four systems, — the Coast Ranges, the Sierra Nevada-Cascade system, the Basin Range system, and the Rocky Mountain system. Each of these systems consists of a number of ranges; for instance, the Rocky Mountain system has many ranges, such as the Wasatch and Uinta ranges.

Denudation, wearing away the ranges, leaves some of the hard rocks standing above the general level. If these elevated portions are long, they are called *ridges* (Figs. 38, 154, 159); if not greatly elongated, *peaks* (Fig. 157). There may be many peaks and ridges in a single range (Fig. 153). More rarely ridges and peaks are formed by folding or faulting (Fig. 155).

FIG. 159. — Diagram to show mountain ridges where denudation has etched inclined hard strata into relief.

There are different kinds of valleys among mountains. The largest of these are the broad plateaus between mountain systems. When they have no outlet to the sea, as in the Great Basin of the West, they are called *interior basins* (p. 22). Smaller basins without outlet are formed between mountain ranges by downfolding. Broad valleys in the Rocky Mountains, some due to folding, others to denudation, are commonly called *parks* (Fig. 165). In the Appalachians, narrow gorges cut by streams across ridges, are called *water gaps* (Figs. 172, 463, 467). A mountain *pass* (Figs. 158, 187) is a low portion of a mountain divide. Passes are usually caused by denudation, where streams head together on opposite sides of a divide. Their position is often due to the presence of a weak rock.

Summary. — *The names cordillera, system, range, ridge, and peak are applied to mountains or parts of mountains. The names interior basin, park, water gap, and pass are applied to mountain valleys.*

67. Climate of Mountains. — The temperature of the air decreases 1°, on the average, for every 300 feet of elevation.

Therefore, high plateaus and mountains rise into the cool upper layers of the air. Indeed, many mountains rise so high that there is perpetual snow on their summits, and glaciers in their valleys. The line above which there is perpetual snow is called the *snow line* (Figs. 153, 157). Below this is a belt with a climate too cold for tree growth. The line above which trees cannot grow is known as the *timber line* (Figs. 158, 166). These lines are lower on the shady than on the sunny side of mountains, and in the temperate than in the tropical zone.

Mountains in the path of vapor-bearing winds have abundant rainfall on the slopes against which the winds blow (p. 287). The opposite slopes, and the country beyond, are dry, because so much vapor is lost in passing over the mountains. This is well illustrated in northwestern United States, where winds from the Pacific cause abundant rain on the western slopes, but reach the eastern side so dry that the country is arid.

Summary. — *On high mountains there is a line, called the timber line, above which no trees can grow; higher still is a zone of perpetual snow. Mountains are well watered on the side from which vapor-bearing winds blow, and often arid on the opposite slopes.*

68. Denudation of Mountains. — The climate and great elevation of mountains give high power to the agents of denudation. Because the rivers are well above base level, they are able to cut deep gorges (Fig. 167) and canyons. Weathering is also very active, especially on steep slopes above the timber line (Figs. 54, 160), where there is little vegetation to offer protection to soil and rock. In such situations the rock is exposed to sharp contrasts in temperature between day and night; frost action is vigorous; and the strong winds, heavy rains, and melting snows all help to move rock fragments down the steep slopes.

Among high mountains the slopes are often so steep that the rock fragments fall to their base (Figs. 54, 183). Some of this rock waste is carried away by streams, but very often more falls

FIG. 160. — Bare rock slopes above the timber line in the Alps, with streams of waste forming talus slopes and alluvial fans. Here weathering is very rapid.

Fig. 161. — Paths of avalanches through the forest on Hayden Peak, Colorado.

Fig. 162. — Surface of the avalanche that crossed the Simplon Pass road, coming down the valley in the background.

than can be thus removed. In time this forms a mantle of rock waste, or *talus* (Figs. 66, 160), which covers the lower slopes, and, by its smooth, curving outline, forms a striking contrast to the rugged, irregular slopes above. As the talus grows, its slope becomes more gentle, till rocks no longer roll down over it. Then the decay of the fragments forms a soil in which trees may grow and on which farms may be located. Where wet weather streams descend the mountain sides, these talus slopes grade into steep alluvial fans and *débris cones* (Figs. 109, 160).

At all times small fragments of rock are falling from the steep mountain slopes; but, in addition, there is an occasional fall of large masses, forming an *avalanche* (Fig. 161) or *landslide*. In such an avalanche thousands, and sometimes millions, of tons of rock, mingled perhaps with ice, come tearing down the mountain side, destroying everything in their course. Rivers are dammed, villages destroyed, and roads ruined. In the spring of 1901 an avalanche of rock and ice from an Alpine valley descended across the road which Napoleon built over the Simplon Pass (Fig. 162). It ruined a mile or two of the road and utterly destroyed a mountain village. About a century before, a similar avalanche occurred in the same place. Mountains supply many instances of such destructive landslides. They are usually started by frost, or by the effect of rain or melted snow, which saturates the soil or rock, making it so heavy that it can no longer stand in its position.

As a result of rapid denudation, acting on the complex rocks, mountains are cut into a great variety of rugged forms,— peaks, ridges, precipices, gorges, and passes. There are peaks almost impossible to scale, some so steep and sharp-pointed that they are called "needles" and "horns" (Fig. 157); there are ridges that no roads cross; and, in fact, a surface often so rugged that large areas are uninhabited.

Summary. — *River erosion and weathering are very active among mountains, especially above the timber line. Rock fragments, falling from steep slopes, accumulate at their base as talus, débris cones, and alluvial fans; and occasionally larger masses descend as avalanches. By this rapid denudation high mountains are made very rugged.*

69. Resemblance between Mountains and High Plateaus. — Some plateaus are more elevated than many high mountain peaks; it is only very lofty mountains that rise higher than 10,000 feet, and yet there are plateaus which reach that level. These high plateaus are often so carved by vigorous denudation as to closely resemble mountains (Fig. 146). They are, in fact, sometimes called mountains.

The Catskill Mountains, for example, are not mountains in the true sense, but dissected plateaus. In the Catskills, denudation has carved out peaks and deep valleys with precipitous sides; but the nearly horizontal strata prove that they were uplifted as

FIG. 163. — A section showing folded mountain strata (on the right) grading into the horizontal strata of a plateau (on the left). Compare the two portions in ruggedness and elevation.

plateaus, not as mountain folds. Such mountain-like plateaus are usually near mountains, and gradually merge into them (Fig. 163).

Summary. — *Vigorous denudation so sculptures high plateaus, like the Catskills, as to make them resemble mountains in ruggedness; but their strata are horizontal.*

70. Distribution of Mountains. — Although mountains are typical of continents, there are ranges in the open ocean; for example, the New Zealand and Hawaiian islands. The latter are volcanoes rising from the crest of a submarine mountain fold, having a length of 1500 miles. There are many other ranges in the ocean, especially in the South Pacific.

Mountains are common at or near the border of continents (Figs. 20–27). They sometimes fringe the coast, as in the case of the Kurile, Japanese, and Philippine islands, and the East and West Indies. Mountain chains also extend from the land into the sea, forming peninsulas; for example, the peninsulas of Lower California, Kamchatka, Malay, Greece, and Italy. In other places mountain systems form the very border of the continents, rising directly out of the sea. Such a condition

is well illustrated by the Coast Ranges of western North America and the Andes of South America.

Mountains are also found far from the coast; for example, the Appalachians, Rocky Mountains, Sierra Nevada, and the mountains of central Europe and Asia. But most mountains of the interior, when first formed, rose from the sea.

A large number of the mountain systems extend from north to south (Figs. 20–25). It is to this fact that several of the continents owe their shape, — that of a triangle, with the long direction from north to south (p. 23). There are, however, many ranges running east and west, especially in Asia and Europe (Figs. 26, 27). No regular law has thus far been discovered regarding the distribution of mountains.

Summary. — *Mountains occur on continents, both in the interior and along the border, where they form chains of islands, peninsulas, and systems which rise at the very margin of the land. They also form island chains in the open ocean. Some extend north and south, others east and west.*

71. Cause of Mountains. — The explanation of mountains most widely accepted is that of *contraction* (p. 20). As the heated interior of the earth cools and shrinks, the cold crust settles; but it cannot fit the constantly shrinking interior without wrinkling. This causes mountains, which are wrinkles in the earth's crust. You can illustrate this by covering a ball with a thick flannel cover a little too large for the ball, then trying to press it down on the ball. Some parts of the cloth must wrinkle.

There is evidence that mountain folding has occurred again and again in the same place; also that this growth has been slow. Several times, mountain systems have risen in eastern and western United States; but, in the plains between, there has been practically no mountain formation at any period. The same is true of other parts of the earth.

Summary. — *Mountains are wrinkles of the earth's crust, caused by its settling on the cooling and contracting interior. They have been formed slowly and by successive uplifts.*

72. Types of Mountains. — Perhaps the simplest type of mountain is that in which a block of strata has been uplifted, along a fault plane, and tilted (Fig. 155). Such a mountain has one moderate and one steep slope, while the crest is a ridge parallel to the fault plane. Mountains of this type are found in southern Oregon and other parts of the Great Basin. These tilted block mountains may reach a height of 4000 or 5000 feet, a width of 10 to 20 miles, and a length of 50 to 100 miles.

Another simple mountain type is the dome, in which the strata have been raised by the intrusion of lava (p. 127). In

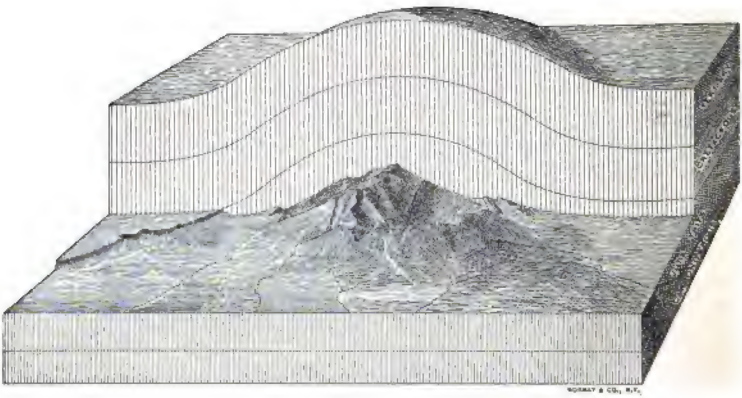


FIG. 164. — The Henry Mountains, 11,000 feet high, with the dome restored as it would probably exist if denudation had removed none of the strata.

such a mountain there is no ridge, but a central area from which the surface slopes in all directions. This type is illustrated by the Henry Mts. (Fig. 164) and others in the West.

A third simple type is the evenly folded mountain, illustrated by the Swiss Jura (Fig. 168) and parts of the Appalachians. When such mountains are formed the surface is thrown into a series of regular waves, like the waves of the sea, the anticlines forming mountain ridges, the synclines, valleys

FIG. 165. — A park, or broad, open mountain valley in the Rocky Mountains. Sultan Mountain is in the distance.

FIG. 166. — The timber line on Alpine Pass in the Rocky Mountains of Colorado.

Fig. 167. — A deep, narrow gorge in the Alps. There are pot holes just above the path on the left, showing that the stream bottom was once at that level. This gorge is being rapidly deepened.

(Fig. 168). When denudation cuts deeply into these, as in the Appalachians, each hard layer is left as a ridge (Fig. 172).

Mountains whose strata are greatly contorted (Fig. 156) and metamorphosed, with much igneous rock, have a far less simple form. Denudation, discovering differences in the rocks, sculptures them into very irregular and rugged outlines. The Rockies and Alps (Figs. 153, 157, 165) are types of such mountains.

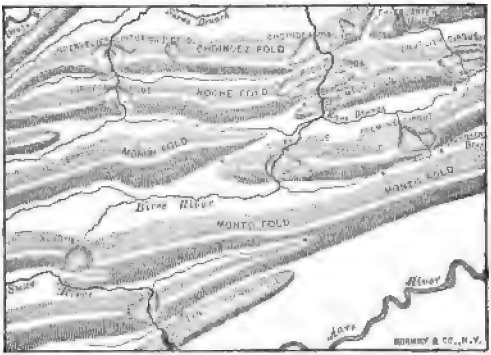


Fig. 168. — Folds of the Jura in Switzerland, showing streams parallel to the folds and crossing them in deep valleys.

Summary.— *There are simple faulted block mountains; domes raised by the intrusion of lava; evenly folded mountains; and very complexly folded mountains. The latter are carved into very irregular and rugged forms.*

73. Life History of Mountains. — Let us assume that the strata of a plain are being folded to form a mountain system. As the strata slowly bend, the surface becomes irregular; and, when the strain becomes too great, the rocks slip along fault planes. This jars the earth, forming earthquake shocks, which may be very severe. Through the deeper fissures, lava may rise, building volcanic cones. Such earthquakes and volcanoes are common in regions of growing mountains (pp. 125, 132).

From the very first the rising land is attacked by the agents of denudation; but this attack increases as the mountains grow higher. Since the mountains are not worn down

as rapidly as they are elevated, they continue to grow higher, reaching above the timber line and even into the zone of perpetual snow. Then glaciers extend down the valleys.

Down-folding forms broad valleys between the ridges; and streams cut narrow gorges across them. The durable rocks are etched out into ridges and peaks, the weak rocks are cut away, forming valleys and passes. In this stage the surface is so irregular that few people are able to live among the mountains. Such mountains, illustrated by those of western North and South America, the Himalayas, and the Alps, are *young mountains.* Find pictures of young mountains in this chapter.

The time comes when uplift ceases; but denudation continues to broaden the valleys and lower the peaks and ridges. As the mountains are lowered, glaciers disappear, and, in time, even the highest peaks may come below the timber line. Such mountains, which have lost the ruggedness of youth, may be called *mature;* the Appalachians and the mountains of New England, Norway, and Scotland, are examples (Figs. 170, 172, 188, 189, 192, 193, 455). Their slopes are forested, their valleys tilled.

Further lowering may continue until the mountains are reduced to a series of low, rolling hills; or, further still, to a surface almost as level as a plain. Such a surface is known as a *peneplain* (almost plain) (Fig. 171). The mountains are then *old*, and are, like plains, adapted to dense settlement. New York City, Philadelphia, Baltimore, and Washington are situated on such old, worn-down mountains. These ancient mountains, known as the Piedmont belt, extend from New England to Alabama, east of the Appalachians.

After being worn to low relief, a mountain region may be reëlevated, and caused to start on a new life history, as has been the case with the Appalachians. Then denudation may etch the ridges of hard rock into relief again, and form broad valleys where the strata are weak (Figs. 172, 173, 192, 193). The broad

Fig. 169. — A rugged cliff, ridge, and peak in the Alps, carved out by the active denudation in these young mountains. The house is a summer hotel for tourists.

Fig. 170. — Mature mountains in the Lake District of northwestern England made famous by the poet Wordsworth. The lake is Derwentwater.

Fig. 171. — The upland, or "peneplain," of New England; a worn-down mountain region, uplifted again so that the streams have had new power given them (rejuvenated). This has enabled the streams to sink their valleys into the "peneplain."

FIG. 172. — Ridges of the Appalachian Mountains crossed by the Susquehanna. (Harden's model.) (See also Fig. 192.)

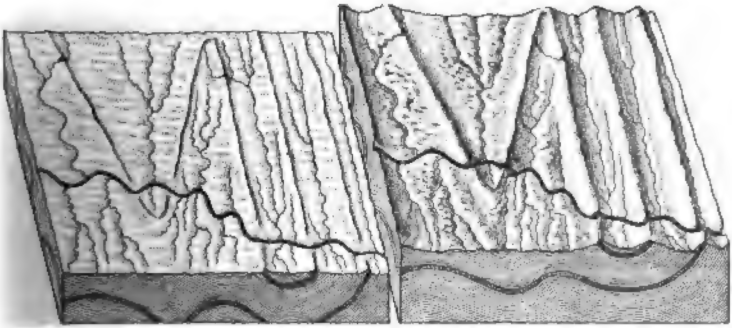


FIG. 173. — To illustrate the origin of the Appalachian ridges. The mountains were worn down to low relief, as in the left-hand figure; then, after uplift, the ridges were etched out. The streams crossing them have cut water gaps, while broad valleys have been developed between the ridges in the weaker strata.

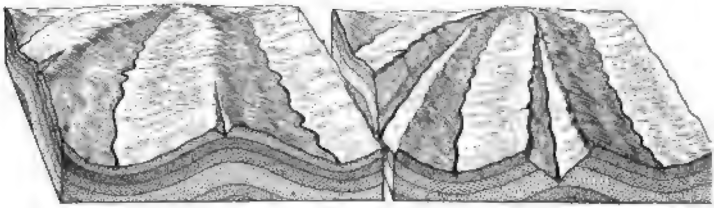


FIG. 174. — The left-hand figure shows two anticlinal ridges each cut into for a short distance by a stream. As the streams cut deeper and grow longer, they reach below a hard layer (the darkest one in the diagram), which, because of its hardness, is left standing as a ridge on each side of the valley (right-hand figure). The law of monoclinal shifting will cause these ridges to retreat away from the stream, thus broadening the valleys in the anticlines, and at the same time narrowing the synclinal valleys. (See also Fig. 179.)

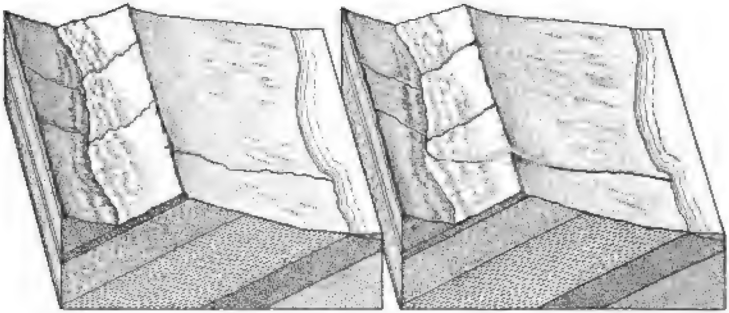


FIG. 175. — In the left-hand figure a stream heads on a divide and flows in a short course toward the right to the sea. This steep slope gives it power to gradually eat backward until it reaches a stream having a long, roundabout course to the sea. It then captures the stream and leads it out to the sea by the shorter course, as shown in the right-hand figure.

Figs. 174, 175, 177, 178, and 179 are introduced for class study, supplementary to the text.

valleys are well settled (Fig. 466), but the ridges are too rough and rocky for farming, and are often timber-covered (Figs. 85, 467). Where streams leave the broad valleys to cross the ridges of hard rock, they flow in narrow gorges, or *water gaps* (Figs. 178, 463, 467), because there has not been time for weathering to broaden valleys in such hard strata.

Summary. — *As mountains rise, the effect of denudation increases, and young mountains are therefore made very rugged. Mature mountains have been lowered and the valleys broadened; and old mountains are still further lowered, and perhaps even reduced to a peneplain. Uplift allows denudation to again etch the hard strata into relief.*

74. The Drainage of Mountains. — In early stages, in consequence of the slopes, numerous short streams flow down the mountain sides in gorges; and longer streams follow the broad valleys between the mountain folds. Here and there the main streams cut deep gorges across low points in the folds (Fig. 168). In such *consequent mountain drainage* there are, at first, numerous lakes held up by the mountain dams. These, however, are soon filled with sediment brought by the mountain torrents. A slight renewal of mountain movement may warp the valleys and form new lake basins (Fig. 296). Some of the Alpine lakes, such as Geneva, are thus explained.

If the elevation of the land ceases, the valleys pass through the stages of youth, maturity, and old age. But the great elevation, and the hard and complex nature of the mountain rocks, make the life history of a river valley in mountains longer than in plains and in most plateaus.

The wearing away of the weak rocks leaves the hard strata standing as divides (Figs. 38, 154, 169). As the surface slowly wears down, the divides still remain on the more durable strata. These mountain strata usually incline, or dip; and, as they are slowly worn away, their crests, that is the divides, not only become lower, but shift to one side

(Fig. 176). This, called *the law of monoclinal shifting*, may be stated as follows: *As denudation lowers a region of inclined strata, the divide migrates in the direction of the dip.*

Mountain divides may migrate for other reasons (Figs. 175, 177, 178). Thus, two streams heading on the same divide are constantly battling for drainage area, and the stronger one pushes the divide back into the territory of its opponent. If it succeeds in robbing its opponent of its headwaters, it is called a *river pirate*. There are various reasons why one stream may have more power than another: one may have more rainfall; or it may have a shorter and steeper slope; or it may have only weak strata to remove while its opponent struggles with hard strata.

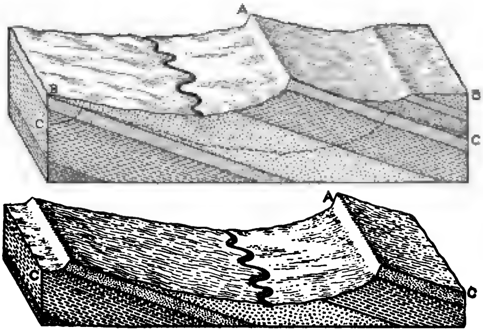


FIG. 176. — To illustrate the migration of divides. A hard layer *A* forms a divide ridge. When the surface has been worn down to the line *CC* (upper figure) the ridge *A* will have migrated to the right, as shown in the lower figure. See also Figs. 174, 179.

There are numerous illustrations of such migration of divides. In the Catskills, for example, the streams descending the steep eastern slope to the Hudson have pushed the divide backward and captured the headwaters of streams that have a long, gentle slope (Fig. 177). The Appalachian rivers — the Potomac, Susquehanna, Delaware, etc., — which cross ridge after ridge (Figs. 172, 192), are believed to have slowly eaten their way across the mountains by headwater erosion and river capture. *Wind gaps* of the Appalachians are also caused by river capture (Fig. 178).

Summary. — *Consequent mountain streams flow down the mountain sides, along the valleys of folding and across the ridges. They*

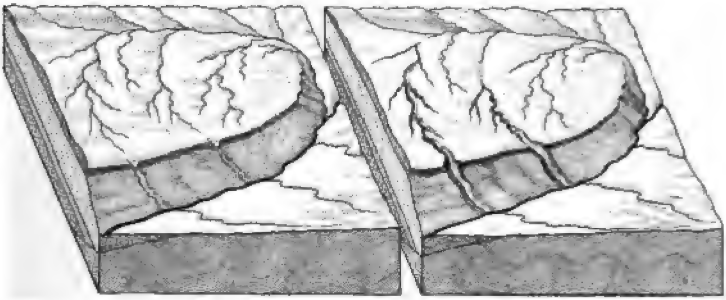


FIG. 177. — The headwaters of a tributary (left-hand figure) rise on a highland and flow a long distance, in a roundabout course, to reach the main stream. Two short streams head in the same region, but flow in steep courses to the main stream. This gives them power to eat back at the divide and rob the long tributary of some of its headwaters (right-hand figure). This condition is somewhat like that in the Catskills. Note that the tributaries of the captured streams join in barb fashion.

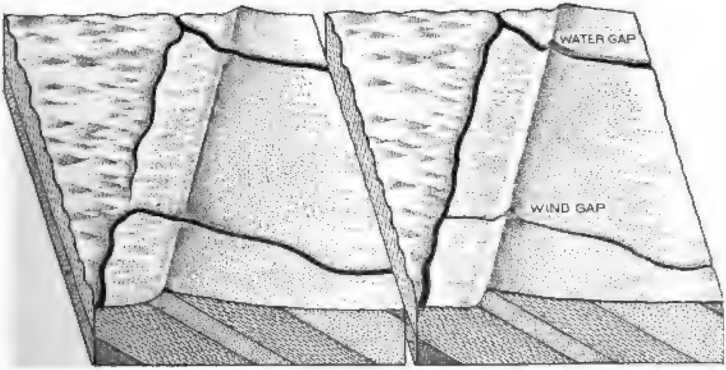


FIG. 178. — In the left-hand figure two streams cross a mountain ridge of hard rock. A tributary of the upper one heads back nearly to the point where the lower one turns to cross the ridge. For some reason (perhaps greater volume) the upper stream has more power to cut into the ridge, thus deepening its valley. This gives to its tributary a slope which permits it to gradually eat backward until it taps the lower stream, drawing it off through the upper water gap. This leaves a *wind gap* where the lower stream formerly crossed the ridge (right-hand figure).

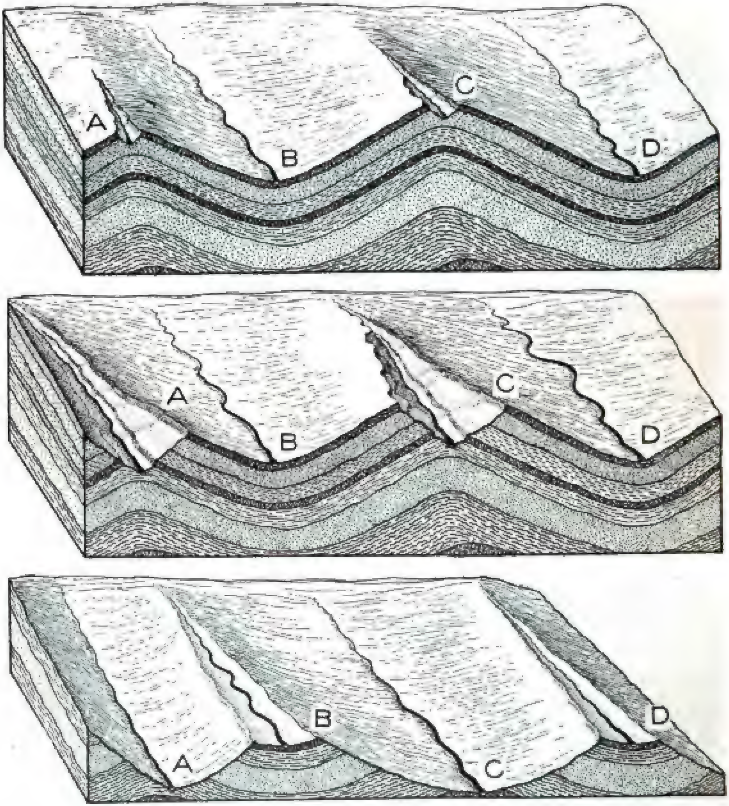


FIG. 179. — The process of monoclinal shifting, illustrated in Figs. 174 and 176, is carried farther in this diagram. In the upper diagram there are four streams, *A*, *B*, *C*, and *D*; *A* and *C* in small valleys in the anticlines, *B* and *D* in broad synclinal valleys caused by down folding. They are consequent on the mountain form. In the middle figure there is little change, excepting that the anticlinal valleys have been lengthened and deepened, this being possible because they are so high that the streams have much power, while the synclinal streams are held back in their work by lakes (not shown here) and hard strata. The lower figure represents a much later stage, in which the surface has been greatly worn down. Monoclinal shifting has pushed the divides away from the anticlinal streams (Fig. 174), therefore broadening their valleys and narrowing the synclinal valleys. This has robbed the synclinal streams of water, and consequently weakened them, while it has increased the power of the anticlinal streams. As a result, the conditions have been reversed from the first stage, and the anticlinal streams, *A* and *C*, flow in broad, deep valleys, while the synclinal streams are in high, narrow valleys, on the tops of synclinal mountains. Instances of this change are found in the Appalachians.

FIG. 180. — The lower slopes of the Alps along the deep valley occupied by Lake Como. These slopes are cultivated, growing olives and grapes, and towns cling to the mountain base wherever there is enough level land, especially on the stream deltas (Figs. 107, 297).

FIG. 181. — The high, snow-covered slopes of the Jungfrau in the Alps, showing summer pasturage above the timber line, and up to the very edge of a glacier.

FIG. 182. — An Alpine valley and village, from which rise the barren, rocky mountain slopes, down which rock waste is streaming, forming alluvial fans.

FIG. 183. — The bare, rocky slopes of the high Alps, among which men do not live. The houses are hotels, open only for two or three months in summer.

are liable to be interrupted by lakes. Slowly they pass through youth, maturity, and old age, unless interrupted by renewed mountain growth. The divides change position by the law of monoclinal shifting, and by headwater erosion. In the latter case the more favorably situated streams capture the headwaters of opponent streams.

75. Settlement of Mountains. — The soil and climate of mountains are usually unfavorable to agriculture, and, in many cases, absolutely forbid it. Large areas are even unfit for the growth of forests. For these reasons mountains are usually sparsely settled (Figs. 157, 158, 183, 185).

The relation of mountains to settlement is well illustrated by the Alps, which rise in the midst of a densely populated land, — Italy on the one hand, France and Germany on the other. If we were to cross the Alps from the Italian side, this is what we should see: first a level plain, the Po valley, dotted with farms and villages, and densely settled. As the land becomes irregular in the foothills, there are fewer people; and, when the mountains are reached, large areas are found with a surface too rocky for cultivation (Figs. 107, 180). Wherever there is soil enough, however, vineyards and groves of olive and mulberry trees are seen on the valley sides.

Higher up, where the climate is cooler, the olive, mulberry, and grapes no longer grow (Figs. 153, 182). There small grain-fields and pasture lands are interspersed with rocky cliffs and forested areas, in which the chestnut is a common tree. Still higher, where the climate is that of the cold temperate zone (Fig. 109), evergreen trees prevail, and only the hardiest grains can be raised. Most of the land that has soil enough is used as pasture, and cows and goats are raised in large numbers. Between the timber line and the snow line there is an area on which no crops can be raised, but where the pastures support herds of cows and goats for a month or two in summer (Fig. 181). Above this is a wild, dreary mass of snow, rock, and ice, where no one can find sustenance (Figs. 157, 182, 183).

Summary. — *Mountains are sparsely settled. Agriculture may flourish at the base, but the area suitable to cultivation becomes smaller the higher one goes, and the climate more and more unfavorable, until, at the snow line, a barren area of snow and rock is reached in which there are no inhabitants.*

76. Mountains as Barriers. — Mountains are barriers to the passage of animals, plants, and men. On a plain, animals and plants spread freely; but the ruggedness and coldness of mountains check, and in many cases prohibit, the passage of animals and the spread of plants. Even the passes of high mountains, like the Alps, have deep snow until summer.

The low Appalachians served as a barrier to the westward spread of the early colonists (p. 308). The Alps (p. 388) have always been an obstacle to man, being crossed only with difficulty and along the few passes. The Himalayas (p. 388) are an even more effective barrier; and the Pyrenees are such an excellent barrier that they serve as the boundary line between two countries. Name other cases where mountains serve as boundary lines.

FIG. 184. — A railway crossing the Andes of Peru. There are three levels here, as in the St. Gothard railway (Fig. 186).

In the past century men have found means of reducing the difficulties of crossing mountains. Excellent carriage roads, rising with gentle slope by great sweeping curves, now cross the principal Alpine passes (Fig. 185). In places where snow-slides and avalanches are common, the roads

FIG. 185. — A mountain road rising up the slopes of the Alps to one of the passes. The Rhone glacier is seen in the middle of the picture. Notice the stream that issues from it, and flows with numerous branches, or with a braided course, over the sediment that it brings from the ice.

Fig. 186. — The St. Gothard railway on the Italian side of the Alps. Notice the three levels. At this point the railway passes through two spiral tunnels in order to rise up the steep slope of the mountain valley before finally plunging into the main St. Gothard tunnel.

Fig. 187. — A summer hotel on a pass near Grindelwald in the Alps. The mountain in the distance, on the right, is the Wetterhorn.

Fig. 188. — The forest-covered slopes of the Adirondacks, with a beautiful lake nestled in a valley in the midst of the forest. (Copyright, 1888, by S. R. Stoddard, Glens Falls, N.Y.)

FIG. 189. — The forest-covered slopes of the White Mountains of New Hampshire, a famous summer resort.

FIG. 190. — Silverton, Col., a mining town in a Rocky Mountain valley. The timber line is seen on the mountain slope.

are covered and protected by avalanche sheds. Railways cross even the lofty Rocky Mountains (Fig. 471), Andes (Fig. 184), and Alps (Fig. 186). They pass up the valleys as far as they can (Figs. 57, 66), curving about, first on one side, then on the other; crossing deep gorges by lofty bridges; tunneling the rock, even by curved tunnels; and finally, when it is no longer possible to climb higher, plunging through a great tunnel into the very heart of the mountain. The St. Gothard tunnel is nine and one fourth miles long; the Simplon tunnel, farther west, is even longer.

Summary. — *The ruggedness and coldness of mountains make them barriers to the spread of plants, animals, and man. Now, by the building of roads and railways, mountains are far less important barriers than formerly.*

77. Mountains as Summer Resorts. — The cool summer climate and the wild and beautiful scenery attract many people to mountains. The numerous mountain lakes which offer opportunities for boating and fishing, and the hunting on the forest-covered mountain slopes, are further attractions. The mountains of New England (Fig. 189), the Adirondacks (Fig. 188) and Catskills of New York, and the Appalachians, are visited each year by large numbers of people. But in winter they are cold, snow-covered, and nearly deserted.

The Alps, the wildest and most beautiful of European mountains, have come to be the greatest summer resort in the world. In the small country of Switzerland, which is only one third the size of Pennsylvania, there are thousands of summer hotels. At every point where many tourists are liable to go, even on mountain trails far from wagon roads, a hotel is sure to be found (Figs. 169, 183, 187). In the height of the season most of these hotels are full to overflowing with tourists from all parts of Europe, in fact, from all the world. One of the leading industries of Switzerland is the entertainment and care of these visitors.

Summary. — *The climate, scenery, boating, fishing, and hunting attract people to the mountains for a vacation.*

78. Mountains as Timber Reserves. — Mountain slopes are so often unsuited to agriculture that in many places the forest

remains (Figs. 85, 188, 189). About one fifth of the surface of Norway is forest-covered, and much of the remainder is either too high or too rocky for trees to grow. The mountains of eastern and western United States still have great timber resources and are the seats of important lumber industries.

Summary. — *Mountains are important timber reserves, because agriculture has not demanded the removal of the forests.*

79. Mineral Wealth of Mountains. — The Alps have little valuable mineral; but the mountains of eastern and western United States, and many other lands, are very rich in mineral. In the West, gold, silver, lead, and copper are most important; but zinc, iron, coal, and building stones are also found. In the mountains of eastern United States, coal, iron, and building stones are the leading mineral products.

The presence of mineral has attracted many people to mountain regions, where otherwise there would be only a sparse population of farmers, herders, hunters, and lumbermen. In rugged mountain valleys, and on arid mountain slopes, cities with thousands of inhabitants have quickly grown up around mining centers.

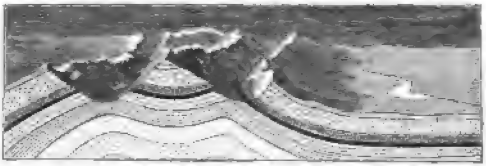


FIG. 191. — To illustrate how folding and denudation bring to light valuable mineral deposits. The black layer may represent a bed of coal. If the strata were horizontal, it might be deeply buried; but folding has raised it, and deep mountain valleys have exposed it to the air.

Mineral beds and veins are revealed by folding of the strata and erosion of valleys in the mountain rocks (Fig. 191). Sometimes they are preserved from erosion by being folded down in the synclines, as in the case of the anthracite coal of Pennsylvania (Fig. 194). This was formed at the same time as the bituminous coal that is found west of the Appalachians; but, during the folding of these mountains, the pressure

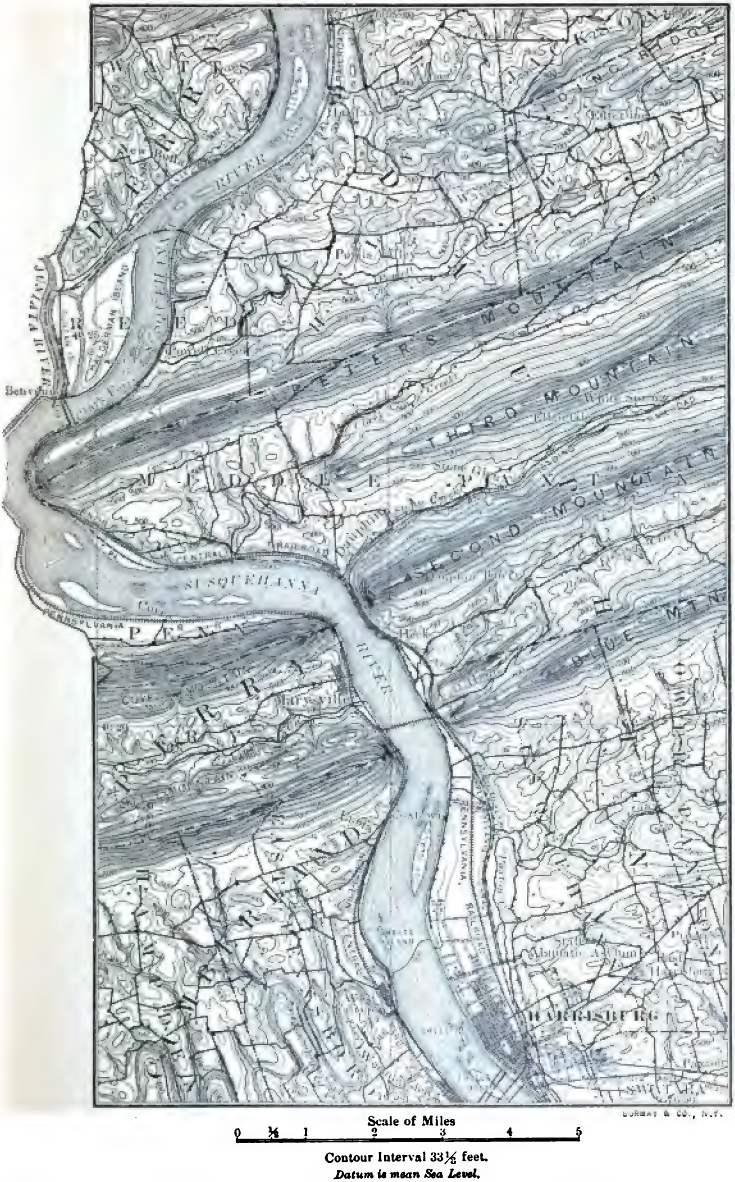


Fig. 192. — Topographic map of Appalachian ridges where crossed by the Susquehanna above Harrisburg, showing the broad valleys and the narrow, steep-sided water gaps. See Figs. 172 and 173. (Harrisburg Sheet, U. S. Geological Survey Topographic Map.)

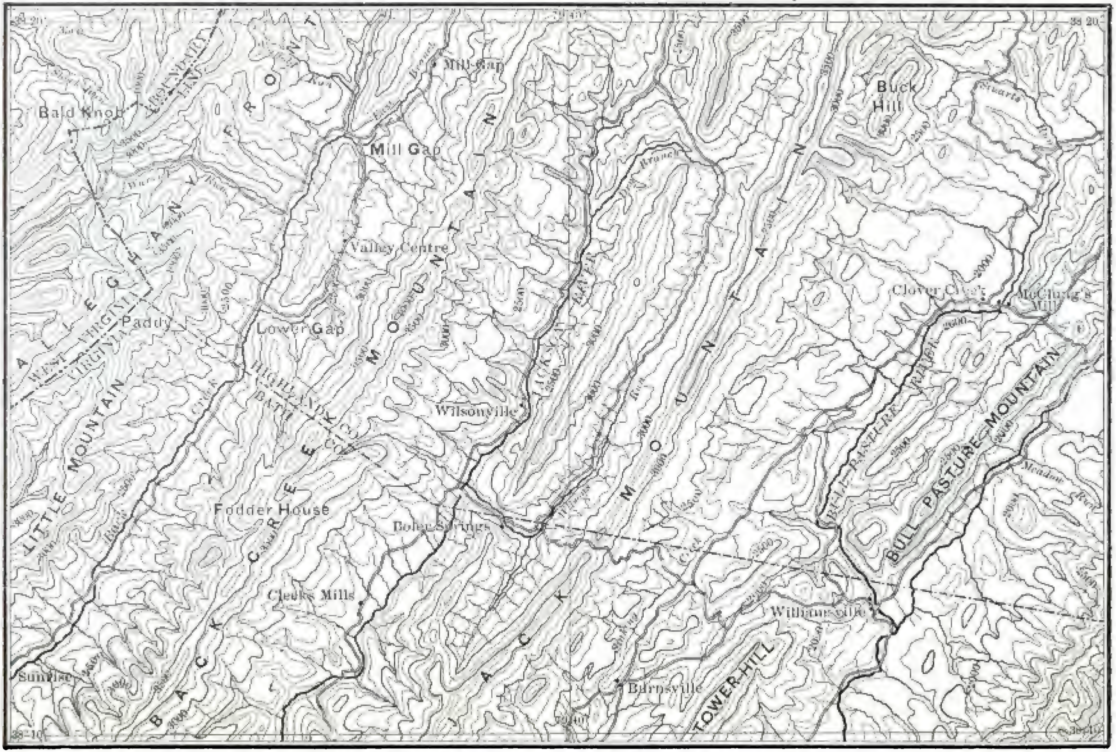


Fig. 193. — The drainage of a mature mountain region in the southern Appalachians. Here the streams are well adjusted to the rock structure, flowing in parallel courses along the lines of weaker strata, receiving short tributaries from the slopes of the ridges, and here and there escaping in gaps across the ridges. Such drainage is characteristic of mature mountain regions, and is said to be *maturely adjusted*. (Part of Monterey, Va.-W. Va. Topographic Sheet, U. S. Geological Survey.)

metamorphosed it to "hard" or anthracite coal. At Scranton, Wilkes Barre, and elsewhere, the anthracite is now being removed from the synclines in which it has been so long preserved.

FIG. 194.— A section of the coal beds (dark layers) at Wilkes Barre. They have been folded down in a syncline, and thus preserved from erosion.

Summary.— *Many mountains contain valuable mineral deposits, which attract settlers. Folding and erosion help to reveal these deposits; and sometimes they are preserved in the synclines.*

TOPICAL OUTLINE, QUESTIONS, AND SUGGESTIONS.

TOPICAL OUTLINE.— 64. **Introductory.**— Influence of mountains on settlement; reasons for studying about mountains.

65. **The Mountain Rocks.**— Position of rocks; faulting; folding; complex folding; Appalachians; kinds of rock; effect of complexity.

66. **Names applied to Parts of Mountains.**— System; range; cordillera; ridge; peak; interior basin; smaller basins; park; water gap; pass.

67. **Climate of Mountains.**— (*a*) Temperature: normal change; snow line; timber line; variation. (*b*) Rainfall: rainy slopes; arid slopes.

68. **Denudation of Mountains.**— (*a*) River erosion. (*b*) Weathering: reasons for activity. (*c*) Talus: cause; form produced; change to farm land; débris cones. (*d*) Avalanches: size; effects; Simplon avalanche; cause. (*e*) Effect of denudation on land form.

69. **Resemblance between Mountains and High Plateaus.**— Resemblance in height; in ruggedness; the Catskills; difference from mountains.

70. **Distribution of Mountains.**— In open ocean; fringing continents,— as islands, peninsulas, and continent borders; in interior; direction.

71. **Cause of Mountains.**— Contraction theory; successive uplifts; slow growth; absence of mountains in certain sections.

72. **Types of Mountains.**— Faulted blocks; domes; regular folds; complex folds; cause, characteristics, and examples of each.

73. **Life History of Mountains.**— (*a*) Young mountains: early growth; earthquakes; volcanoes; increasing denudation; valleys; unfitness for occupation; examples. (*b*) Mature mountains: broadening; lowering; examples; fitness for occupation. (*c*) Old mountains: further reduction;

peneplain; settlement; instance; Piedmont belt. (*d*) Renewed elevation: Appalachians; ridges; broad valleys; settlement; water gaps.

74. **The Drainage of Mountains.** — (*a*) Consequent drainage: stream courses; lakes. (*b*) Life history — compare with plains. (*c*) Monoclinal shifting: nature of process; law. (*d*) River pirates: battle at headwaters; favoring conditions; Catskills; Appalachians; wind gaps.

75. **Settlement of Mountains.** — (*a*) Unfavorable conditions. (*b*) The Alps: the base; the slopes; above the timber line; above the snow line.

76. **Mountains as Barriers.** — Reasons; instances; overcoming barriers, — roads, railways, tunnels.

77. **Mountains as Summer Resorts.** — Attraction; mountains visited in eastern United States; the Alps; importance to Switzerland.

78. **Mountains as Timber Reserves.** — Reasons for forests; instances.

79. **Mineral Wealth of Mountains.** — Alps; the West; the East; effect on settlement; effect of folding and erosion; anthracite coal.

QUESTIONS. — 64. Of what importance are mountains to men?

65. What is the position of the mountain rocks? What differences are there in the folds? In the rocks? What effect has this complexity?

66. What are the following, and what causes each: mountain system, range, cordillera, ridge, peak, interior basin, park, water gap, and pass?

67. What is the snow line? The timber line? How do they vary? What effects have mountains on rainfall?

68. Why are rivers and weathering very active in mountains? What becomes of the fragments that fall? What are the nature, effects, and causes of avalanches? What effect has denudation on mountains?

69. Compare and contrast high plateaus and mountains.

70. In what situations are mountains found? Give illustrations. What about the direction of mountain ranges?

71. State the theory of contraction. How do mountains grow?

72. Give four types of mountains. What are the characteristics of each? How do they differ? Are they alike in any respect?

73. What happens when a mountain is rising? What effect has denudation? What are the characteristics of young mountains? Trace the development through maturity to old age. Give illustrations of each. What is a peneplain? What has been the history of the Piedmont Belt? What changes have occurred in the Appalachians?

74. Describe the consequent drainage of mountains. What is the normal life history? What causes lakes? How does the law of monoclinal shifting operate? What are river pirates? Why do they succeed? Give illustrations. Explain wind gaps (Fig. 178).

75. Why are mountains sparsely settled? How does the appearance of the Alps change from base to summit? How do the occupations vary?

76. Why are mountains barriers to the spread of animals and plants? Give illustrations. How are these barriers now overcome by men?

77. What attracts people to mountains? Give instances.

78. Why is there much forest among mountains? Give illustrations.

79. What mineral deposits are found among mountains? What effect have mountains in revealing and protecting mineral deposits?

SUGGESTIONS. — (1) Slowly dry an apple. Notice how the skin wrinkles as the inside grows smaller through the evaporation of the water. Compare this with what is happening in the earth. (2) Find out how the tire of a wagon wheel is put on, and why it fits so tightly. (3) Get a metal rod, and have a thick metal ring made just too small to fit over it. Heat the ring red-hot and see if it goes over the rod. Have another ring made to fit the rod exactly. Heat the rod and see if the ring will go over it. What does this show? (4) See suggestion for covering a ball, given on page 99. (5) It is not very difficult to make an apparatus for imitating the folding of rocks. Of one-inch boards make a long, narrow box, say 2 feet long, 5 inches wide, and 8 inches deep, open at one end and the top. Place four or five thin layers of wax, differently colored, on the bottom. At the open end apply slow, steady pressure, best obtained by using a screw, like that which sets a vise, fastened to a board that just fits into the end of the box. Before applying the pressure, place over the wax layers enough of shot to nearly fill the box. After pushing the layers a few inches, remove the shot, unscrew one side, and the layers will show folding. A simpler experiment may be made by taking a series of pieces of thick cloth and felt, cutting them to the same size, and pressing them up with the hand. (6) Is your home among mountains, or have you ever been among mountains? What is the nature and position of the rocks? Do the mountains rise above the timber line? Are they young, mature, or old? Are they well settled? Why? Are there forests? Mineral? Are they resorted to in summer? Why?

Reference Books. — KING, *Mountaineering in the Sierra Nevada*, Scribner's Sons, New York, 1902, $1.50; LUBBOCK, *Scenery of Switzerland*, Macmillan Co., New York, 1896, $1.50; RUSSELL, *Southern Oregon*, 4th Annual U. S. Geological Survey, p. 435; TARR, *Physical Geography of New York State*, Chapter III, Macmillan Co., New York, 1902, $3.50; HAYES, *Physiography of the Chattanooga District*, Part II, 19th Annual U. S. Geological Survey, p. 9; WILLIS, *The Northern Appalachians*, *National Geographic Monographs*, American Book Co., New York, 1895, $2.50; HAYES, *The Southern Appalachians*, same; WILLIS, *Mechanics of Appalachian Structure*, Part II, 13th Annual U. S. Geological Survey, p. 217.

CHAPTER VII.

VOLCANOES, EARTHQUAKES, AND GEYSERS.

VOLCANOES.

80. Graham Island. — South of Sicily, in 1831, a new volcano was born. During the eruption large volumes of steam rose into the air, carrying up fragments of lava. The expansion of the steam in the melted rock caused numerous cavities, and broke the lava into bits of porous ash and pumice. Some of the lightest ash drifted away in the wind; much of the pumice was light enough to float on the water; but many of the heavier fragments fell back near the outlet, building a cone which rose 200 feet above the sea and had a circumference of almost three miles. With this single eruption the life of the volcano seems to have ended; and soon the waves cut the loose ash cone away, leaving a shoal to mark its site.

Other volcanoes, some in the sea, some on the land, have become extinct after a single gasp; but most volcanoes have a longer and more varied life. From some, ash is always erupted; from others, streams of liquid lava; and from many, now ash, now lava. Some erupt freely and at frequent intervals; others have violent outbreaks, following long periods of quiet. These differences between volcanoes may best be illustrated by studying a few typical ones.

Summary. — *Graham Island became extinct after a single eruption of ash and pumice, formed by the blowing up of melted rock by included steam. Other volcanoes have a much more varied history.*

81. Stromboli. — Between Sicily and Vesuvius, in the Lipari Islands, is the ever active volcano Stromboli. It is a small cone, about 6000 feet from bottom to top, half its height being above sea level. Steam rises from a crater on one side of the cone, and the steam clouds glow with light from the melted lava, which always stands in the crater. Every few minutes the steam erupts masses of lava; and sometimes there is a mild eruption which throws pieces outside the crater. The cone is made of such fragments.

FIG. 195. — Vulcano, one of the Lipari Islands, in full eruption. This cone is now inactive.

Summary. — *Stromboli is a volcano made of fragments of lava thrown out by mild eruptions.*

82. Eruptions of 1902 in the West Indies. — On the 8th of May, 1902, the beautiful city of St. Pierre, in Martinique, was wiped out of existence by a terrible volcanic eruption from Mont Pelé (Fig. 197). Between 25,000 and 30,000 people were killed in a few seconds, and only one person in St. Pierre, a prisoner in the jail, escaped death. On the previous day there was a destructive eruption from the volcano of La Soufrière, in the neighboring island of St. Vincent.

The last eruption of Mont Pelé was in 1851; and in 1812 there was a terrific and destructive eruption of La Soufrière. The inhabitants of St. Pierre had almost forgotten that danger lurked in the slumbering volcano; and, though the outbreak of 1902 was preceded by distinct warnings,

few heeded them. On April 25 warm water was reported in the old crater; later, dust-laden steam rose from it; then a lake rose, overflowing the crater rim on May 5, and sending a deluge of hot water and mud down a valley.

On the 8th of May came the eruption. A huge column of steam, expelled with great force, bore heated sulphurous gases, dust, ashes, and stones high in the air. The eruption was not nearly so violent as many other eruptions; but, owing to the following peculiar condition, its effect was very disastrous. On the side toward St. Pierre there was a break in the crater wall, with a valley leading toward the city. Down this valley some of the steam, with its load of hot rock fragments and gases, rushed with the violence of a tornado, destroying everything in its path. It overturned trees and houses, and even carried a hollow iron statue, 11 feet high, a distance of 50 feet. Most of the deaths were probably caused by breathing the steam and hot ashes.

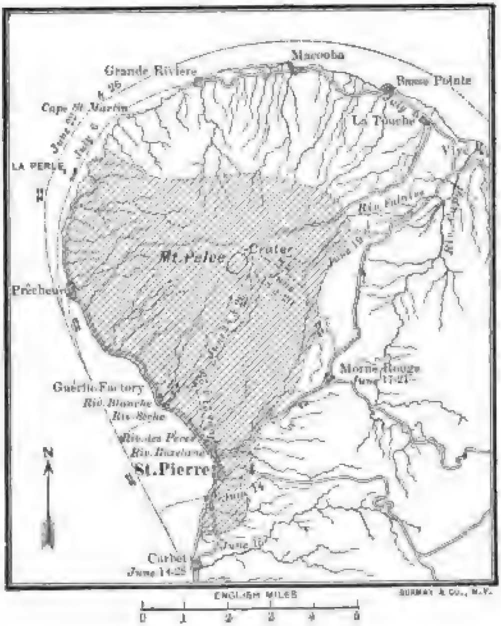


FIG. 196.—The vicinity of Mont Pelé. The shaded area shows the zone of destruction.

FIG. 197. — The ruins of St. Pierre, from a photograph taken June 14. Mont Pelé is in the background.

FIG. 198. — Valley of the Roxelane, near St. Pierre, as it appeared May 22, 1902, — the trees killed and the surface covered with volcanic ash.

(From photographs loaned by E. O. Hovey of the American Museum of Natural History.)

FIG. 199. — Vesuvius from Pompeii, whose ruins are now largely excavated. The remnant of Monte Somma forms the ridge on the right, while the present cone of Vesuvius rises in the middle.

FIG. 200. — A street in Pompeii. On this the ruts of the chariot wheels may still be plainly seen. Ash completely covered all the buildings and filled every crevice compactly. Parts of the city are not yet uncovered.

There have been several later outbursts, all, like the first, erupting ash, with no flowing lava and with no destructive earthquake shocks. The eruptions have built a cone 1500 to 2000 feet high in the old crater, and the ash has fallen over the whole island (Fig. 198) and the sea round about. After the eruption of June 6, a quarter of an inch of ash fell upon a ship over 100 miles from the volcano. At a distance from the volcano the ash deposit is thin; but on and near the cone it is several feet deep, resembling freshly fallen snow. During each eruption the condensed steam causes heavy rains, which wash vast quantities of loose ash down the steep slopes in destructive *mud flows.* Sometime — no one can foretell when — the eruptions will cease, probably to break out again when energy enough is accumulated.

Summary. — *In May,* 1902, *after a long period of quiet, Mont Pelé and La Soufrière burst forth in eruptions of ash, causing much destruction. There have been numerous eruptions since then, and vast quantities of volcanic ash have been thrown out upon the islands and the sea round about. The condensed steam, forming rain, has washed much ash down the volcano side, causing mud flows.*

83. Vesuvius. — At the beginning of the Christian era, Vesuvius, like Pelé, had long been inactive, and people had no fear of it. It had been quiet, or *dormant*, for centuries, and was not even recognized as a volcano. Farms and villages dotted the slopes of Monte Somma (Fig. 201), as it was called, and cities were located at its base. In the year 79 it broke forth in a terrible eruption which buried the farms and villages beneath ash, and destroyed Pompeii and Herculaneum.

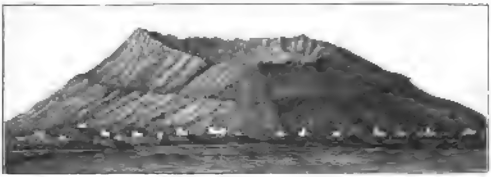


FIG. 201. — The form of Vesuvius, or Monte Somma, before 79, according to Strabo. Only a part of the crater rim now stands (Fig. 199), the present cone rising on the site of that part of the crater nearest us.

Before the eruption there were frequent earthquakes, one of which partly destroyed Pompeii; and, finally, a terrific explosion occurred by which half the crater wall was blown away. The ashes rose thousands of feet in the air, settling on all the country round about. The naturalist Pliny, admiral of the Roman fleet, who was at Misenum (near C. Miseno, Fig. 202), started toward the mountain and lost his life. Letters of Pliny's nephew to the historian Tacitus, telling of the death of his uncle, are the only description of the eruption that we have.

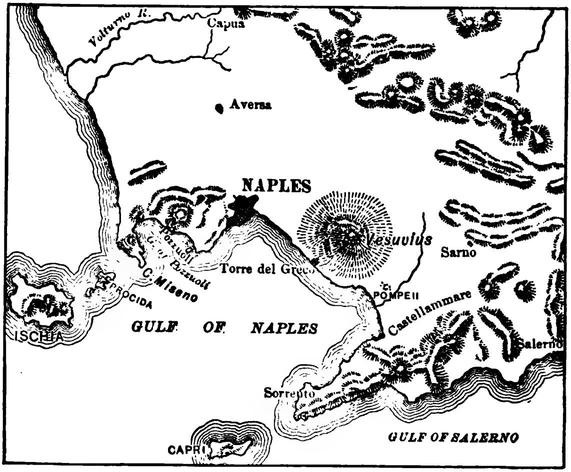


FIG. 202.—Map of the Bay of Naples. There are numerous volcanic cones from Pozzuoli to Ischia.

The day was changed to the darkness of night by a heavy cloud of ash; hot ashes and stones fell all about; the air was filled with sulphurous gases; the ground was violently shaken; there was fierce thunder and lightning; and the cries of terror from the people, who rushed madly about, added to the din. Thousands of people were undoubtedly killed, though there is no record of the number, nor even of the villages destroyed.

Pompeii and Herculaneum have been discovered and partly

Fig. 203. — Vesuvius in eruption in 1872, showing the steam rising from the crater; also from the lava that is flowing down the slopes.

Fig. 204. — The ordinary condition of Vesuvius. The lava in the foreground was erupted in 1858.

Fig. 205. — The cone of Vesuvius, in moderate eruption, July 5, 1895.

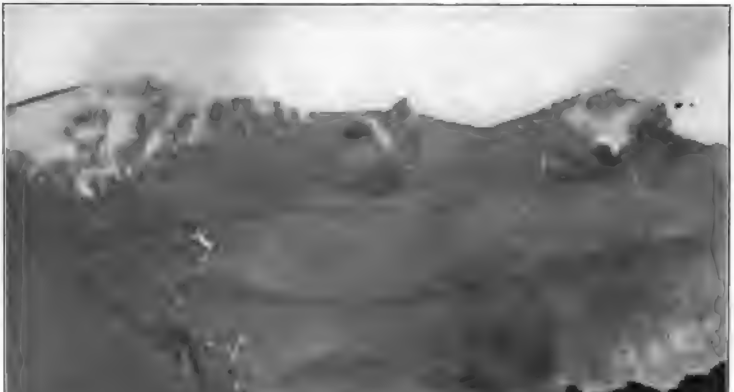


Fig. 206. — A view into the crater of Vesuvius. This photograph was taken during the above eruption, when the lava was drawn out of the crater. At ordinary times the crater is so filled with steam that one cannot look far down into it.

FIG. 207. — Monte Nuovo, a small ash cone, at the head of the Gulf of Pozzuoli (Fig. 202), which was thrown up during an eruption in 1538. It has not erupted since, and its slopes are now cultivated.

FIG. 208. — The crater of another volcano at Pozzuoli, also extinct. Steam and sulphurous gases, forming sulphur crystals, still rise in this crater, and vegetation is unable to grow where they rise.

FIG. 209. — Etna with steam rising from its crater. Several small cones, built during eruptions, are also shown on the flanks.

FIG. 210. — An eruption on the flanks of Etna, showing steam rising from one of the small cones. The distant, snow-covered peak is Etna.

excavated (Fig. 199). From these excavations we learn what the life of the Romans was on the day of that fearful outbreak nearly 1900 years ago. The houses have been so well preserved beneath the ash that even pictures painted on the walls are still quite perfect. It is a wonderful experience to walk through those deserted streets (Fig. 200), and to see how the people lived, and what they did, as if they had left but yesterday. Yet it is a picture of life almost at the time of Christ.

Since 79 Vesuvius has had many eruptions, some violent, some moderate (Fig. 205), some of ash, some of lava (Fig. 203). The remnant of old Monte Somma still stands on one side of the present cone, which rises 4200 feet above the level of the Bay of Naples (Fig. 202). At most times visitors may go to the very edge of the crater (Fig. 206). Standing on the side from which the wind blows, one looks down into a deep hole, out of which vast quantities of steam rise with a roar, bearing sulphurous gases. Every few seconds there is a slight explosion, when masses of red-hot lava are thrown up, often higher than the crater wall. At night the lava in the crater causes a glow on the cloud that overhangs Vesuvius.

Occasionally the volcano grows more active; then hot stones rise so high that they fall on the crater edge, and it is unsafe to stand there. This may increase until the stones fall some distance beyond the crater. The small cinder cone that surrounds the crater is made of these loose fragments.

Now and then lava issues from the cone, flowing in a great stream, sometimes clear to the sea. The recent flows form great black, rugged scars on the volcano side (Fig. 204); the older ones are partly decayed and covered with a soil. There is an observatory on the slope of Vesuvius for the study of the volcano, and for the prediction of eruptions.

Vesuvius is only one of several volcanic cones in the Bay of Naples (Figs. 207, 208). The famous lake Avernus is in a volcanic crater; the island of Ischia is a volcano (Fig. 202); and

there are several others in the same region. All of them have been long extinct, though hot water, steam, and gases still rise in some places. There are numerous proofs that changes in level of the land have accompanied the volcanic activity of this region (Fig. 37).

Summary. — *In the year 79, after being long dormant, Vesuvius broke forth in violent eruption, partially destroying the cone and burying Pompeii and Herculaneum, which have been well preserved beneath the volcanic deposits. Since then Vesuvius has had many eruptions of ash and lava, some of them very violent. Ordinarily it is so quiet that one may go to the very edge of the crater, from which steam constantly rises, bearing upward masses of lava. In the neighborhood there are extinct volcanoes.*

84. Etna. — The greatest volcano in the Mediterranean is Etna, on the eastern end of Sicily. Steam rises from its crater (Fig. 209), and every few years there is an eruption. Then lava issues from fissures in the mountain side and flows in enormous masses down the slopes, even to the sea, often destroying villages on the way. There are scores of small cones, 200 to 300 feet high, built along these fissures (Figs. 209, 210).

Etna rises 10,870 feet above the sea, and at its base has a circumference of over 60 miles. It is so high that, although oranges and bananas grow at its base, the climate at the top is frigid. This great cone is made entirely of lava and ash forced out from within the earth by steam. The recent lava flows, those only a few score years old, are barren masses of black rock too rough to cross. But this lava decays so readily, and forms such a fertile soil, that in a century portions of a flow are fit for cultivation. Soil is often gathered in baskets and placed between the lava blocks for the planting of grapevines.

Summary. — *The huge cone of Etna is made of lava, issuing mainly as great flows from fissures in its flanks. This lava decays quickly, forming a fertile soil.*

85. Krakatoa. — For a century the small volcanic island of Krakatoa, near Java in the Straits of Sunda, was dormant. In August, 1883, it broke forth in the most terrific eruption that civilized man has known. A large part of the cone, together with ash from below, was hurled high into the air, and the site of the destroyed cone was occupied by water 1000 feet deep (Fig. 220). Every vestige of life on the island was destroyed, and its surface was deeply covered with ash.

For miles around, the sea was so thickly covered with pumice that the movement of vessels was interfered with. The finer ash was thrown so high into the air that it was drifted all round the earth, causing brilliant sunsets in Asia, Europe, and America.

So violent was the explosion that a great air wave was started which passed three times around the earth. Windows were broken 100 miles from the volcano, and the sound of the explosion was heard more than 150 miles away. A water wave was also caused which spread all over the Pacific, being measured on the coasts of Africa, Australia, and California. Near the volcano this wave washed over the land to a height of 50 to 100 feet, killing 35,000 people.

Since then Krakatoa has been quiet. It may have become extinct; but more probably it is only dormant, and will again burst forth when the pent-up steam once more gathers sufficient energy to force its way to the surface.

Summary. — *After a century of quiet, Krakatoa burst forth, in* 1883, *in the most violent eruption known. Half the cone was blown away; ash fell all about, and was drifted far and wide by the winds; a great air wave passed three times round the earth; and a water wave spread over the Pacific. Since then the volcano has been quiet.*

86. Hawaiian Volcanoes. — There are numerous volcanic cones in the Hawaiian Islands (Fig. 224), most of them extinct. The two highest are Mauna Loa and Mauna Kea, which, with the smaller Kilauea, are on the island of Hawaii (Fig. 211). This island, the greatest volcanic mountain in

the world, rises nearly 14,000 feet above sea level, and 30,000 feet above the sea floor.

On the top of Mauna Loa is a great crater two or three miles in diameter. This is partly frozen over, but steam rises from cracks in the surface, and in one part there is a lava lake, from which jets or fountains of lava rise, sometimes several hundred feet. A similar condition exists in the crater of Kilauea; but Mauna Kea is extinct. Such extensive craters (Figs. 212, 213) are called *calderas*.

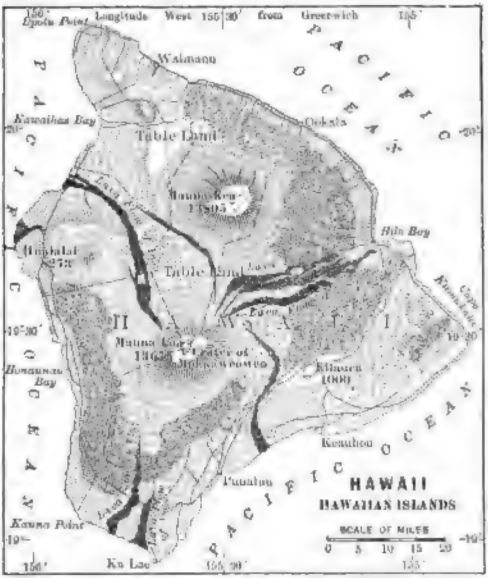


FIG. 211.—The dark areas represent lava flows which start from fissures.

The lava slowly rises, overflowing the crater floor and freezing on it (Fig. 212), as water sometimes flows over the ice on a pond. Before the lava rises high enough to flow out over the rim of the crater, its weight and the steam pressure usually open a fissure in the mountain side through which the lava is drained (Fig. 211). This occurs, on the average, once in about seven years, and no violent ash eruptions have ever been recorded. The fissures are usually formed above sea level, but sometimes occur beneath the sea. Some of the lava streams are 30 or 40 miles long and 2 or 3 miles wide.

FIG. 212. — Lava lake, frozen at the surface, in the crater of a Hawaiian volcano.

FIG. 213. — Lava lake in the crater of a Hawaiian volcano.

Fig. 214. — Mt. Shasta, California. On the right is Shastina, a newer cone on the flanks of the main volcano. Both these cones are extinct; but Shastina still has a crater, while the crater of Shasta has been destroyed by denudation.

Fig. 215. — Crater Lake, Oregon, the deepest lake in North America. The little island, called Wizard Island, is a cone built up from the bottom of the crater since it collapsed.

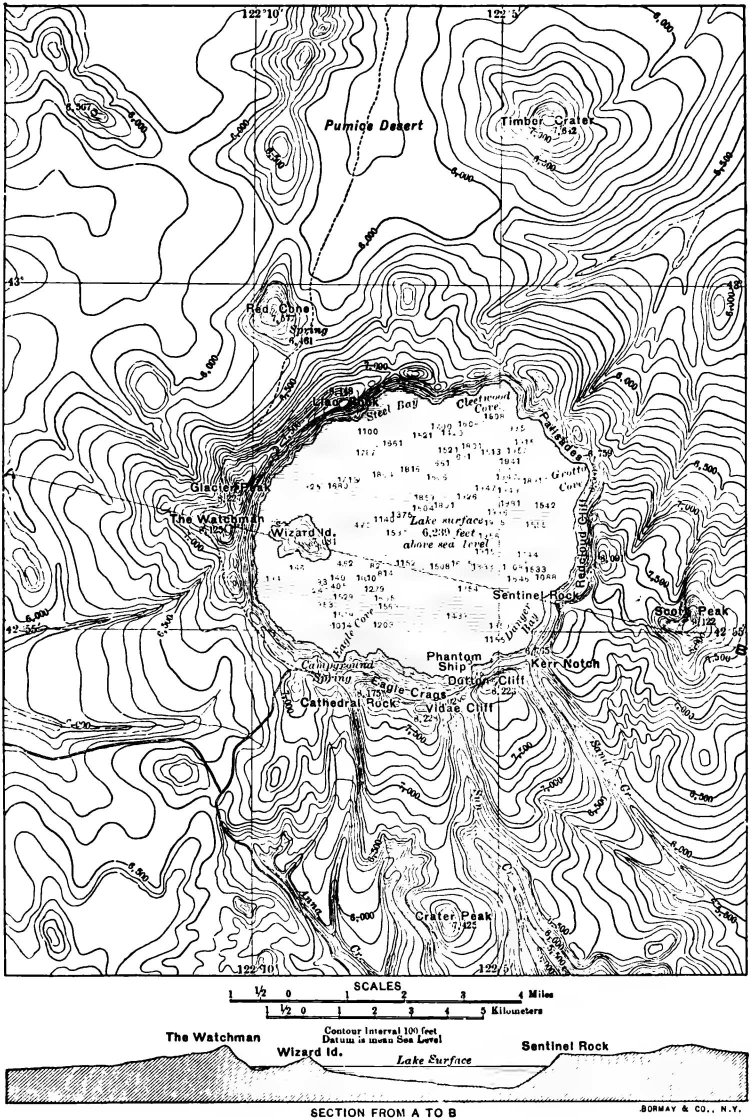


Fig. 216. — Topographic map of Crater Lake. Notice the other smaller craters and cones near by. A section through the mountain, along the line *AB*, is shown at the bottom. (Crater Lake Special Sheet, U. S. Geological Survey Topographic Map.)

FIG. 217. — Flowing lava in Hawaii, 1881.

FIG. 218. — Lava cascade, similar to the above, with the lava cooled.

An earthquake shock accompanies the opening of the fissure, and huge volumes of steam rise from the glowing lava that rushes forth. At first the lava flows rapidly down the mountain side; but it soon cools and solidifies at the surface (Figs. 217, 218). Then the movement becomes much slower. The frozen crust is broken and rolled along by the movement of the lava beneath, and liquid lava may burst through the solid front at any point. The lava front advances for weeks, always more and more slowly, and years may pass before it entirely cools.

Summary. — *Hawaii, the greatest volcanic mountain in the world, has two active volcanoes with huge craters, or calderas. In these are lava lakes which steadily rise, once in about seven years being drained through fissures in the mountain sides. The lava at first flows rapidly; but, as it cools on the surface, its rate of flow is checked.*

87. Mt. Shasta and Lassen Peak. — This extinct volcano (Fig. 214), whose elevation is over 14,000 feet, resembles Etna in form. From its snow-covered top small glaciers descend into the higher valleys, and on its flanks is a later cone.

South of Shasta is the extinct cone of Lassen Peak, and near its base an ash cone about 650 feet high (Fig. 235). The size of trees that have grown in the ash indicates that it was erupted about 200 years ago. A still later lava eruption has dammed a stream, forming Snag Lake, in which are snags of trees killed by the rise of the water. It seems probable that this lava flow is not much over a century old. There are other recent lava flows in various parts of the West.

Summary. — *Shasta is a lofty extinct volcano; but at Lassen Peak, near its base, there have been recent eruptions of ash and lava.*

88. Crater Lake. — Another extinct volcano in western United States is occupied by Crater Lake in Oregon. This lake, which is about 2000 feet deep, lies in a huge crater, or caldera (Fig. 216), between 3000 and 4000 feet in depth, and about 6 miles in diameter. It has been proved that a lofty volcano (Fig. 219) rose where the caldera now stands. The removal of lava from

beneath the cone allowed it to collapse, forming the caldera, in which a later eruption has built a small ash cone (Fig. 215).

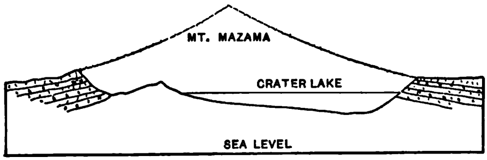


FIG. 219. — Section of Crater Lake, with the old cone, named Mt. Mazama, restored by the dotted line.

Summary. — *Crater Lake occupies a huge crater, or caldera, formed by the draining off of lava from beneath, causing the cone to collapse.*

89. Materials Erupted. — Every volcanic eruption is accompanied by vast quantities of steam, and smaller amounts of sulphurous and other gases. These gases are commonly called "smoke," and the glow of light reflected from the melted lava is popularly termed "flame."

If the eruption is moderate, melted rock usually flows out, and, in cooling, forms *lava flows* (Figs. 217, 218). Expansion of steam in the pasty lava makes many small rounded cavities, especially near the top; and the surface is broken by the movement of the lava after a crust has been formed. In violent eruptions the expansion of the steam blows the lava to pieces, forming *scoria*, *pumice*, and *ash*. These are so light and porous that they float in water, and the fine ash even remains suspended in the air.

Lumps of lava thrown into the air, cooling in oval, twisted masses, are known as *volcanic bombs* (Fig. 236). They vary from a few inches to many feet in diameter. During eruptions the condensation of the steam causes heavy rains, accompanied by vivid lightning. The rain often washes down much loose ash, forming *mud flows*.

Summary. — *Steam and other gases accompany all volcanic eruptions. Lava comes from moderate eruptions; ash, pumice, and scoria from violent ones. Volcanic bombs are also thrown out; and rains wash down the ash, forming mud flows.*

90. The Forms of Volcanic Cones. — A volcano is a conical peak with a crater at the top. If the eruptions are of ash the cone is steep, because the fragments that fall back near the vent have a slope as steep as loose ash will stand (Fig. 221). On the other hand, cones made of flowing lava are broad and have a low slope (Fig. 221). (Compare Figs. 223 and 224.)

One reason for these differences is that lava flows away as a liquid; another, that some of it starts, not from the top, but from fissures on the slopes of the cone (Figs. 210, 211); and a third that it all remains on the cone, while in ash volcanoes a large part is drifted away by the winds. When the material is now ash, now lava, as in Vesuvius, the cone has a slope intermediate between that of lava and ash.

The crater of a volcano may be so large, perhaps from one to five miles in diameter, as to deserve the name *caldera.* In addition to the calderas of the Hawaiian Islands (p. 120) and Crater Lake (p. 121), there are calderas in Italy, the Eifel district of Germany (Fig. 225), and other places. The craters on the moon (Fig. 14) are enormous calderas. Calderas may be caused either by collapse of the cone, or by violent explosions which blow the top of the cone away. In some cases, as in Krakatoa (Fig. 220), explosions wreck the cone and make it irregular.

Summary. — *Ash cones have a steep slope, while lava cones are broader and more gentle in slope. Cones consisting of both ash and lava have a slope between the two. Calderas are huge craters caused either by the collapse or by the blowing away of the tops of cones.*

91. Distribution of Volcanoes. — There are thousands of volcanic cones, only about 300 of which are known to be active. The great majority of these cones are in or near the sea, far the greatest number being in the mountains and islands which partly encircle the Pacific Ocean (Fig. 222).

The many lofty cones in the Andes, Central America, and southern Mexico are in this belt. Associated with it is the volcanic belt of the Lesser Antilles, 500 miles long, in which Mont

Pelé and La Soufrière are situated. Most of the islands of the Lesser Antilles are volcanic. From Mexico northward, through western United States, are hundreds of volcanic cones, all either dormant or extinct. Among the best known of these are Mt. Ranier, Mt. Shasta, Mt. St. Helens, and Mt. Hood.

The Aleutian Islands, which inclose Bering Sea, form a volcanic chain 1600 miles long, including 57 volcanoes, some of which are very vigorous. From Kamchatka southward, along the Kurile, Japanese, and Philippine islands, there is another great chain of volcanoes. The East Indies have numerous active cones, and this chain swings down to New Zealand.

Practically all the small islands of the open Pacific and Indian oceans are volcanoes. Even the coral atolls are volcanic cones with a veneer of coral.

There are volcanic areas in the continents of Europe, Asia, and Africa, including a line extending from central Africa to Asia Minor; also Mt. Ararat; volcanoes in the Caucasus Mountains; and a number in the Mediterranean near Greece, and in and near Italy.

The islands of the open Atlantic are volcanic, and some of them are active. Iceland has a number of volcanoes, some of which have had terrific eruptions. The Faroe Islands are ancient volcanoes, and there were formerly volcanoes in the British Isles. In the Azores Islands, which are all volcanic, there are hundreds of cones (Fig. 226), some of which were in eruption during the last century. The Bermuda islands are a coral group on a volcanic cone. The Cape Verde, Canary, and other islands farther south, including St. Helena, the prison home of Napoleon, are all volcanoes.

In spite of the great numbers of cones, they are really exceptional land forms. By far the greater part of the earth's surface is now free from volcanic action; and large areas have never been disturbed by eruptions. In other places, as in eastern United States, central France (Fig. 227), and the British Isles, volcanic action long ago died out. Both at the present time and in the past, volcanic activity has been associated with mountain growth.

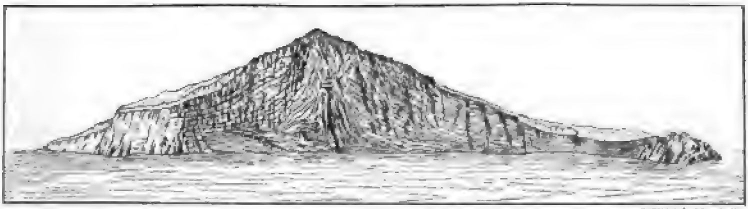


FIG. 220. — The half of Krakatoa left after the eruption.

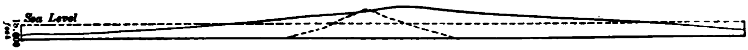


FIG. 221. — The slopes of two volcanoes, one ash (dotted), the other lava. The latter, represented by the continuous line, may be considered to be Mauna Loa. Not only is the ash cone steeper, but it contains much less material, because so much has been drifted away by winds and ocean currents. See also Figs. 223, 224.

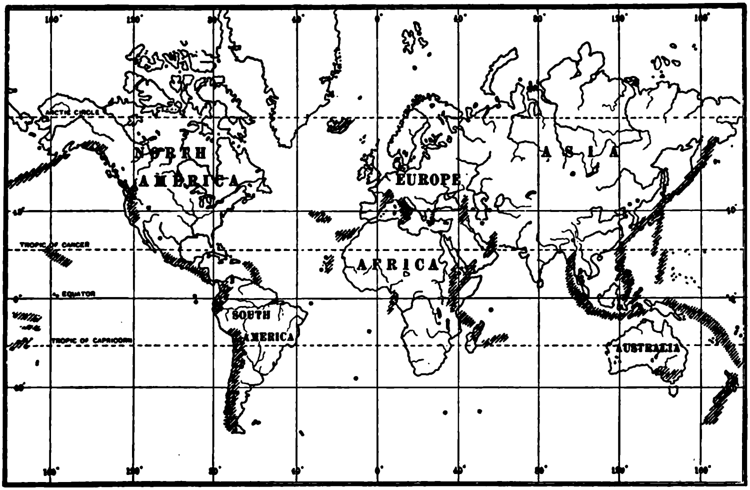


FIG. 222. — The distribution of volcanoes. The shaded sections show the main areas, and the dots locate some of the active or recently extinct volcanoes.

FIG. 223. — Chimborazo, Ecuador, 20,500 feet high; so high that, though under the equator, it is snow-covered.

FIG. 224. — A volcanic lava cone in the Hawaiian Islands. Compare its low slope with that of Chimborazo. See also Fig. 221.

Fig. 225. — Caldera in the Eifel region of Germany. This is a region of extinct volcanoes; but they have become so recently extinct that lakes still occupy their craters.

FIG. 226. — A volcanic cone in the Azores. It is so recent that it has a perfect crater. The stone walls by the roadside are made of lava blocks.

FIG. 227. — Volcanic peaks in the Auvergne region, a volcanic region in central France. The peaks on which the buildings are situated are remnants, or necks, of volcanoes partly destroyed by denudation.

Summary. — *The majority of volcanoes are in or near the sea, the greatest belt being in the chain of mountains and islands which partly encircle the Pacific. There are many volcanic islands in the open Pacific, Indian, and Atlantic oceans, and in the Mediterranean. Volcanoes are exceptional land forms. They have never been present in some places and have become extinct in others.*

92. Cause of Volcanoes.—The immediate cause for a volcanic eruption is undoubtedly the explosive force of pent-up steam. It is believed that this steam is caused by water that percolates down to the melted rock. As it slowly accumulates, it finally gains force enough to push its way to the surface and carry some of the melted rock with it.

It is probable that the folding of the mountain rocks squeezes the lava upward until it reaches places so near the surface that water is able to enter it and force it the rest of the way. Faults formed during mountain growth furnish pathways for the rise of this lava.

When mountains stop growing, volcanic activity dies out. For this reason western United States, which in the last geological period was a region of intense volcanic activity, is now almost, if not quite, free from active volcanoes. There may yet be eruptions in the West; but unless there is a renewal of mountain growth, these eruptions will probably not be numerous.

Summary. — *Water, descending from the surface, comes in contact with melted rock, probably squeezed upward during mountain folding. This forms steam and forces the lava to the surface, often along faults. When mountain growth ceases, volcanic activity dies out.*

93. Lava Floods. — In western United States, in addition to volcanoes, there were great lava floods which escaped from fissures and deluged the surrounding country. They were perhaps squeezed out as a result of mountain growth, somewhat as water rises through a crack in the ice of a frozen pond. The greatest of these floods was in the valley of the Snake and Columbia rivers (Fig. 476), mainly in Oregon,

Idaho, and Washington, where an area of fully 200,000 square miles is covered with lava. By these lava floods, which extended up valleys and surrounded mountains, as lake water does, an irregular land surface was changed to a great lava plateau. Deep canyons show a depth of 3000 to 4000 feet of lava, layer on layer. In some places, as in the Cascade Ranges, blocks of this lava have been broken and tilted to form mountains.

Throughout the Far West there are other instances of lava floods, for example, in the Yellowstone Park. Similar floods have been formed in other parts of the world, as the plateau of the Deccan in India, which in extent rivals the Columbia lava plateau.

At present such lava floods are nowhere issuing from the earth. The nearest approach is in Iceland, where lava, welling from fissures, has built a broad plateau. When such a fissure is partly closed, leaving only one or two places for the lava to escape, volcanic cones are built along it. This accounts for some of the chains of volcanic cones.

Summary. — *Great lava floods, rising through fissures, and perhaps squeezed out by mountain growth, have deluged large areas of country in western United States and other regions. Iceland has the nearest approach to this condition at present. The closing of most of a fissure allows the formation of a line of volcanic cones.*

94. Lava Intrusions. — Not all the lava that starts toward the surface reaches it. For example, when eruptions cease, the vent of a volcano becomes filled with solid lava. This is called the *volcanic neck* or *plug* (Figs. 34, 227, 231). The long, narrow sheets filling the fissures, through which lava escapes on the flanks of a volcano, are called *dikes* (Fig. 34). In the neighborhood of volcanoes, similar dikes are intruded into the rocks (Fig. 232) deep in the earth. These and other forms of intruded rocks are brought to light by denudation.

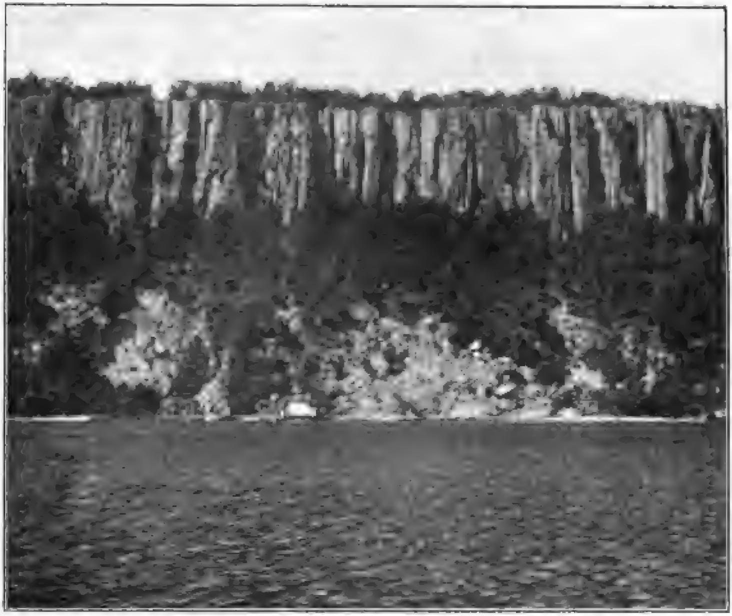


FIG. 228. — Intruded lava sheet forming the Palisades of the Hudson. Notice the columnar appearance due to jointing. (See Fig. 230.)

FIG. 229. — Mt. Tom, Massachusetts, a ridge formed by a sheet of lava that was intruded into the sandstone strata several geological ages ago, then tilted and worn into its present mountain form.

FIG. 230. — Columns caused by the jointing of an ancient intruded sheet of lava at Giant's Causeway, Ireland. The columnar jointing is the result of the breaking of the lava as it cooled. (See Fig. 228.)

FIG. 231. — Mato Tepee, Wyoming, a volcanic neck or plug. All the other material has been removed by denudation, leaving the hard lava plug standing above the surrounding country. (See also Fig. 227.)

Sheets of lava have been intruded between strata (Fig. 34). Such intruded *sheets* or *sills* frequently have a well-developed jointing, which causes them to break in columns, usually with five or six sides (Fig. 230). The Palisades of the Hudson (Fig. 228), Mts. Tom (Fig. 229) and Holyoke, Mass., East and West Rock at New Haven, Conn., the trap mountains near Orange, N. J., and the lava sheets at Fingal's Cave in Scotland and the Giant's Causeway in Ireland are intruded sheets of lava.

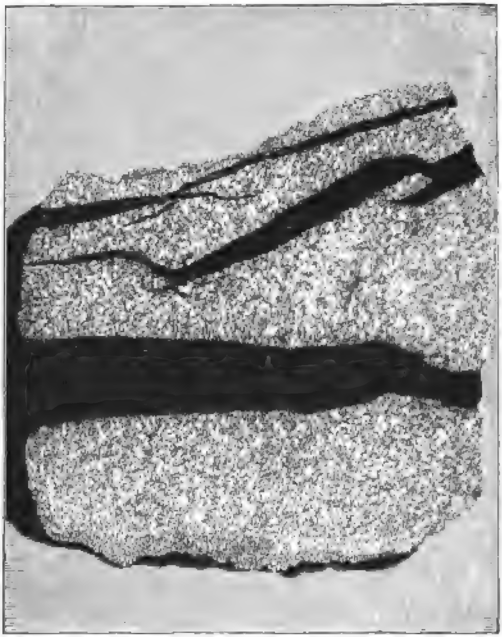


FIG. 232. — Dikes (black) crossing a granite rock.

A large mass of intruded lava which raises the strata to form a dome is called a *laccolith*, or rock lake (Figs. 164, 233). Irregular masses of intruded lava form *bosses* (Fig. 34), often made of granite. These are found in the cores of old, worn-down mountains, as in the Adirondacks, New England, Scotland, and Norway.

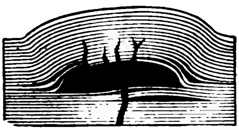


FIG. 233. — Ideal section through a laccolith (see also Fig. 164).

Summary. — *Various forms of intruded igneous rocks — necks, dikes, sheets, laccoliths, and bosses — are caused by the rising of lava that does not reach the surface. The wearing down of the surface by denudation brings these intruded lava masses to view.*

95. Life History of a Volcano. — While a volcano is active the cone usually grows, because each eruption adds material to it. A dormant volcano may, however, break forth in such violent explosive eruption that the cone is wrecked and its size and form changed (Figs. 199, 220). Or, by the opening of a new outlet, the lava may be drained from beneath

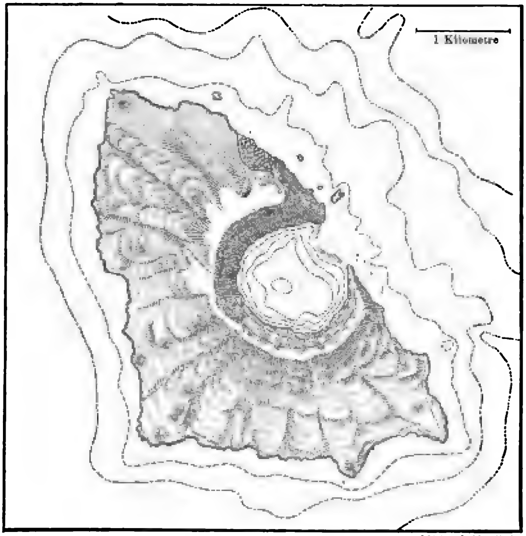


Fig. 234. — St. Paul, a volcanic island with the crater wall breached by the waves, forming a crater harbor.

the cone, causing it to collapse (Fig. 219). But these causes for changes in the form of volcanoes are accidental.

Throughout the life of every volcano the agents of denudation are at work tearing it down; but so long as it is active, fresh supplies of lava or ash tend to repair the damage. When the volcano becomes extinct, however, denudation has full sway. At first the crater is occupied by a lake (Figs. 216, 225), but the rim is slowly destroyed and the

lake drained. Streams gully the cone with deep ravines and gorges, until it bears little resemblance to a volcano. As the cone is slowly worn down, the hard core of lava in the volcanic neck resists denudation better than the looser beds of porous lava and ash. It therefore, remains above the surface as a central divide for radiating streams (Figs. 227, 231, 237). In western United States there is every gradation from the perfect cone to the volcanic neck remnant.

If a volcano stands in the sea, the waves have a large share in its reduction (Fig. 234). At first, steep cliffs are cut, on which the waves beat with such force that no boat can land. As these cliffs are pushed back into the land, the crater may be reached and a crater harbor be opened (Fig. 234). Further wave cutting may entirely consume the volcano, leaving only a shoal to mark its site.

Summary. — *During activity a volcano grows by addition of lava or ash faster than denudation wears it away; but explosion or collapse may change its size or form. When extinct, however, volcanoes are slowly worn away, the last remnant being the hard volcanic neck. Waves aid in the destruction of cones in the sea.*

96. Importance of Volcanoes. — The most noticeable effect of volcanoes is the destruction of life, — human, plant, and animal. The ash, lava, steam, gases, hot water, mud flows, lightning, and earthquakes that accompany eruptions all contribute to this destruction. Nothing in nature is more terrible than a volcanic eruption.

Yet volcanoes have some beneficial effects. The burial of organic remains beneath ash and lava has preserved fossils that throw much light on the history of former life on the globe. The eruption of Vesuvius in 79 has preserved a record of Roman life that we could not in any other way have obtained. Lava flows have also covered and preserved deposits of precious metal, as in California, where some of the gold mining is carried on in ancient river gravels beneath old lava flows (Fig. 238).

Volcanoes have formed many lakes, like Nicaragua in the Isthmus of Panama. Volcanoes and lava floods have helped make grand scenery. There are few finer sights than a large, snow-capped volcanic cone, like Etna, Ranier, Hood, or Shasta.

Lava soils are usually very fertile; for example, one of the most productive wheat regions of the country is the Columbia valley, with its rich volcanic soil. Lava and ash have supplied much of the material of which the sedimentary strata are made; and igneous rocks have supplied underground water with much valuable mineral for deposit in veins. Lava also heats the water, thus giving it more power to dissolve minerals. The presence of lava in western United States has had a very important influence on the formation of the valuable mineral veins of that region.

Summary. — *Volcanoes are very destructive to life; but they have some beneficial effects. They preserve records of past life, and occasionally valuable minerals; they cause lakes; they aid in the making of scenery; their soils are usually fertile; they have helped supply material for the sedimentary strata; and they have aided in the formation of mineral veins.*

EARTHQUAKES.

97. (A) *Cause.* — During mountain growth a jar, or earthquake, is sent through the rocks when they slip along fault planes. Sometimes, as in Japan, in 1891, the surface of the ground on one side of a fault plane is raised during the shock (Fig. 239). Volcanic explosions, and the rush of lava into fissures, forming dikes, also cause earthquakes. In fact, any jar to the rocks, as an explosion of gunpowder, the falling in of caverns, or an avalanche, will cause an earthquake. The jar may be so slight that it can be detected only by delicate instruments; or it may be so violent as to cause widespread destruction.

(B) *Occurrence.* — Since earthquakes are so commonly caused by the breaking of rocks and by the movements of lava, volcanic regions are especially liable to them. Indeed,

FIG. 235. — Cinder Cone and the lava flow which dammed Snag Lake near Lassen Peak, Cal.

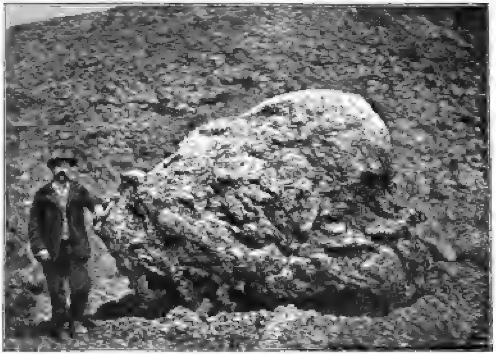


FIG. 236. — A volcanic bomb on the slopes of Vesuvius.

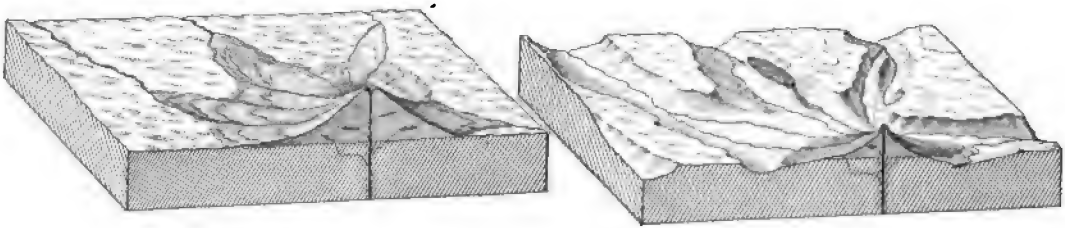


FIG. 237. — To illustrate the destruction of a volcano. On the left the cone is shown with its lava flows; on the right the cone has been mostly worn away, and streams have deeply carved the land. Small areas between the streams are left capped with lava, forming buttes, and the volcanic neck rises above the general surface.

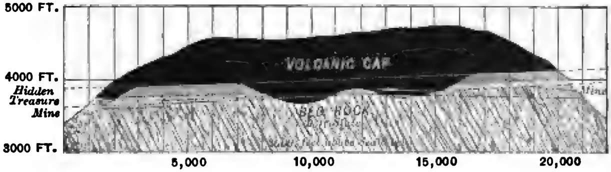


Fig. 238. — Section of a gold mine in California, beneath an ancient lava flow (volcanic cap). The circles indicate old river gravels, containing gold, which the lava flows covered.

Fig. 239. — Fault which caused the earthquake shock of 1891 in Japan. By this fault the road in the middle of the picture was raised several feet on the farther side of the fault plane. (See Figs. 241, 242.)

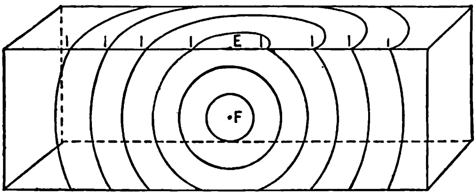


Fig. 240. — A drawing to illustrate the movement of an earthquake wave outward in all directions from the focus, *F*. The shock reaches the surface first at *E*, the epicentrum, and at later and later periods on the circles marked *I*.

a map of the distribution of volcanoes might also serve as a map of frequent earthquakes. To be sure, there have been violent earthquake shocks far from volcanoes; for example, those of Lisbon, Portugal, in 1755, southern Arkansas in 1812, and Charleston, S.C., in 1886. Such shocks are usually due to the slipping of rocks along a fault plane.

(C) *Characteristics.* — The center, or *focus* (Fig. 240), of an earthquake may be thousands of feet beneath the surface. From it the jar passes through the rocks in all directions (Fig. 240), in much the same way as a shock passes through a table when it is struck a heavy blow. The point above the focus, where the shock is first felt at the surface, is called the *epicentrum.*

At the epicentrum the movement of the earth is vertical, and the shock is most violent. As the distance from the epicentrum increases, the shock is felt with less and less violence. The Charleston earthquake was detected by delicate instruments as far away as Ontario, Canada.

In an earthquake shock the ground may not rise and fall more than an inch, and yet do great damage. The earthquake is rarely a single shock, but usually a succession of jars, perhaps near enough together to give the appearance of a shaking of the ground. Very often one earthquake quickly follows another; for example, in 1783 nearly 1000 shocks were felt in Calabria, in southern Italy. In this case the rocks were probably slipping along a fault plane, and each slip sent out an earthquake. The many earthquakes that precede a volcanic explosion are no doubt due to the breaking of the rocks by the attempt of the steam-filled lava to escape.

(D) *Effects.* — Violent earthquakes are very destructive (Figs. 241, 242). They often cause avalanches, which dam streams and form lakes ; and the shaking of the ground sometimes forms depressions, in which lakes and ponds gather. Trees are thrown down; cracks, in which plants and animals are swallowed up, are opened in the ground ; and great destruction of life is caused by the overturning of houses

(Fig. 241). In consequence of the danger from falling houses, people who live in countries where earthquakes are frequent, build their houses so that they will withstand ordinary shocks. Even with this precaution, thousands of lives are sometimes lost in a single shock. If the shock is in the sea, a water wave may be started which causes much destruction on low coasts (p. 186).

Summary. — *Earthquakes are jars in the rocks, resulting from faulting, volcanic action, and other causes. They are most common in volcanic regions, but sometimes occur elsewhere. An earthquake, usually a series of shocks, is most violent at the epicentrum (point above the source, or focus, of the shock), diminishing in intensity in all directions from it. Earthquakes form lakes, open cracks in the ground, and throw down trees and houses, causing great destruction of life. If in the sea, a destructive water wave may be started.*

HOT SPRINGS AND GEYSERS.

98. Underground water is often heated by buried masses of lava or other causes. Where this heated water rises to the surface, usually through a fissure, it forms a *hot spring;* and if it occasionally gushes out, it is called a *geyser.*

The rising hot water always bears mineral substances in solution, some of which may be deposited near the spring. Such deposits are found around the hot springs (Figs. 243, 474) and geysers (Figs. 244, 473) of Yellowstone Park. Hot water is sometimes encountered in mines, and it is known that many veins of gold, silver, copper, and other valuable metals have been deposited by hot water on the walls of fissures.

There are geysers in New Zealand, Iceland, and the Yellowstone National Park — all volcanic regions. The mineral deposits made around these are often very beautiful in form and color, and they sometimes build a cone, through the crater of which the geyser erupts (Figs. 244, 473).

FIG. 241.—Destruction caused by the Japanese earthquake of 1891 (Fig. 239). All this damage was done to houses that were built very lightly and thus able to withstand ordinary earthquake shocks.

FIG. 242.—Damage to a railroad bridge by the Japanese earthquake of 1891. Note how the earth was shaken from beneath the track where it leaves the bridge.

Fig. 243. — Hot spring deposits in the Yellowstone Park. These deposits are carbonate of lime (calcareous tufa), and they build little basins in which the hot water stands, trickling over the edge and forming icicle-like deposits.

Fig. 244. — Giant Geyser, Yellowstone Park, in eruption. The deposits made around the geysers are of silica (siliceous sinter).

The geysers are exceedingly interesting. Old Faithful erupts every 65 minutes, with such regularity that the time of each outburst can be accurately predicted. With each eruption a great mass of hot water and steam is thrown to a height of over 100 feet. The Minute Man geyser erupts a small column every few minutes to a height of only a few feet. Other geysers erupt very irregularly, and some have become extinct. The differences between the geysers suggest the probability of several explanations for their eruptions.

Those that erupt regularly, like Old Faithful, seem to be due to the following cause. There is hot water in a narrow tube; and this is heated, perhaps by an adjacent lava mass, until the boiling point is reached. The boiling point of water rises under pressure; therefore, it may be necessary to raise the temperature to 250° or more before boiling begins down in the tube. When the boiling point is reached steam forms, but the narrow tube prevents its easy escape. It then lifts the column of water and causes some of it to flow away from the geyser crater. This overflow removes some of the water column and therefore reduces the pressure on water that is already boiling at 250°. This removal of pressure at once lowers the boiling point; and, since a large mass of water has a temperature near 250°, it suddenly changes to steam. This expels the water with a rush. The time between eruptions depends upon the length of time required to heat the water down in the tube to the boiling point.

Summary. — *Hot water, rising from underground, forms hot springs; or, if it rises in eruption, geysers. It bears and deposits mineral substances, both at the surface and in the fissures through which it rises — in the latter case sometimes forming valuable mineral veins. Some geysers erupt regularly, others very irregularly.*

Topical Outline, Questions, and Suggestions.

Topical Outline. — 80. **Graham Island.** — The eruption; materials erupted; the cone; its destruction; other volcanoes.

81. **Stromboli.** — Location; size of cone; nature of eruptions.

82. **Eruptions of 1902 in the West Indies.** — Destruction of St. Pierre; La Soufrière; previous eruptions; warnings; eruption of May 8; cause of destructiveness; effects of later eruptions; material erupted; distribution of ash; mud flows; probable future.

83. **Vesuvius.** — (*a*) Eruption of 79: previous condition; settlements on slopes; warnings; effect of eruption; our knowledge of the eruption; conditions accompanying eruption. (*b*) Pompeii: importance of its excavation. (*c*) Condition since 79: difference in eruptions; present condition; ordinary quiet; increase in activity; lava eruptions; observatory. (*d*) Other volcanoes of Bay of Naples.

84. **Etna.** — Position; eruptions; great height; decay of the lava.

85. **Krakatoa.** — Former eruption; eruption of 1883; ash on the sea; air wave; water wave; conditions since eruption; future.

86. **Hawaiian Volcanoes.** — (*a*) Island of Hawaii: its volcanoes; its height. (*b*) The craters: lava lakes; calderas. (*c*) Lava flows: rising in crater; draining through fissures; length of flows; nature of flow.

87. **Mt. Shasta and Lassen Peak.** — Shasta; ash cone; recent eruptions.

88. **Crater Lake.** — Size of lake; cause of caldera.

89. **Materials Erupted.** — Steam; other gases; meaning of "smoke" and "flame"; lava flows; effect of steam explosion on lava; bombs; mud flows.

90. **The Forms of Volcanic Cones.** — Ash cones; lava cones; ash and lava cones; calderas; wrecked cones.

91. **Distribution of Volcanoes.** — Number; general location; belt encircling Pacific, — South America, Antilles, western United States, Aleutian Islands, eastern Asia; other chains, — Pacific and Indian oceans, continents, Mediterranean, open Atlantic; areas free from volcanoes; areas of extinct volcanoes; association with mountains.

92. **Cause of Volcanoes.** — Immediate cause; effect of growing mountains; condition in western United States.

93. **Lava Floods.** — (*a*) Columbia valley: cause; area; lava plateau; thickness; later tilting. (*b*) Other areas. (*c*) Present condition: general absence of lava floods; Iceland; relation of fissures to volcanic cones.

94. **Lava Intrusions.** — Volcanic necks; dikes; how revealed; sheets or sills: illustrations; laccoliths; bosses.

95. **Life History of a Volcano.** — Normal growth; effects of explosion; of collapse; denudation; the volcanic neck; volcanoes in the sea.

96. **Importance of Volcanoes.** — Destruction of life; preservation of fossils; of human records; of mineral; formation of lakes; effect on scenery; on soils; on sedimentary rocks; on mineral veins.

97. **Earthquakes.** — (A) *Cause:* faults; volcanic action; other causes. (B) *Occurrence:* volcanic regions; other regions; illustrations. (C) *Characteristics:* focus; nature of shock; epicentrum; distance trav-

eled; repeated shocks; explanation of repeated shocks. (D) *Effects:* avalanches; lakes; cracks in the ground; overturning houses; sea waves.

98. **Hot Springs and Geysers.** — Cause; nature of geysers; mineral deposit at surface; mineral veins; distribution of geysers; geyser deposits; eruption of geysers; explanation of geyser eruptions.

QUESTIONS. — 80. State the history of Graham Island. What causes ash and pumice? How do many volcanoes differ from this one?

81. Where is Stromboli? State its characteristics as a volcano.

82. What reasons were there for expecting an eruption? Why was the eruption so destructive at St. Pierre? What were its effects? What was the nature of the material erupted? What causes mud flows?

83. What was the condition of Vesuvius in 79? Tell about the eruption of 79. How has it been of importance? What has been the subsequent history of Vesuvius? What is its present condition? What other signs of volcanic activity are there near Vesuvius?

84. Describe Etna and its eruptions.

85. Describe the eruption of Krakatoa and its effects.

86. Describe the Hawaiian volcanoes and craters. Describe the eruptions. What is the nature of the lava flows?

87. What is the condition of Shasta? Near Lassen Peak?

88. What has been the history of Crater Lake?

89. What substances are erupted from volcanoes?

90. How do ash and lava cones differ? Why? What are calderas?

91. Trace (Fig. 222) the principal chains of volcanoes (named in text) in the belt which partly encircles the Pacific. Where else are volcanic chains found? Are volcanoes found everywhere?

92. What is the immediate cause for volcanic eruptions? What relation is there between growing mountains and volcanoes?

93. Describe the lava floods of the Columbia valley. Where else were lava floods formed? How may volcanic cones succeed fissure eruptions?

94. What are volcanic necks? Dikes? Sheets or sills? Give illustrations. What are laccoliths? Bosses? How are they brought to light?

95. What may affect the form of a volcano before its extinction? What is its history after extinction? What is the case in the sea?

96. State the important effects of volcanoes.

97. (A) What are the causes of earthquakes? (B) Where are they most frequent? Why? What explains violent earthquakes elsewhere? (C) What is the focus? The epicentrum? What is the nature of the shock? (D) What are the effects of earthquakes?

98. What are hot springs and geysers? What do the waters carry? Where are geysers found? How do they vary? Give the explanation of regularly erupting geysers.

SUGGESTIONS. — (1) Illustrate the formation of volcanoes. Take an ordinary wooden box, for example a soap or shoe box, remove the cover and turn it on its side with the bottom toward the class and the open side toward the teacher. Extend a glass tube through the top of the box and blow sand gently through it. A cone will be built with a crater in the center. The force of the eruption may be made to vary, and many phases of volcanic eruptions may be imitated. The sand is best blown through by means of foot bellows, and the result will be more satisfactory if the lower part of the tube is expanded into a bulb that is partly filled with sand. (2) In the same way, force melted wax up to form a volcano. Have a branch tube extend off, reaching an inch or two above the top of the box. Keep its end plugged until the wax covers it, then open it and plug the main tube, allowing the wax to escape through the side tube to illustrate the eruption of lava from the sides of a cone. If the wax solidifies in the tube and interferes with the experiment, warm the tube. (3) With a little ingenuity wax can be forced between layers of clay and cardboard, forming laccoliths; or into fissures cut through the layers, forming dikes. (4) Look for dikes. If your home is along the rocky coast of New England, they may easily be found. Study them and tell what you observe. (5) Students in the Connecticut valley, New York City, and east central New Jersey should be given an excursion for the study of the trap sheets. Look for jointing. Look for the rock strata above or below the lava. How do they differ from the trap? Make careful observations. (6) Earthquakes may be imitated and studied by jarring a slab of stone or a table top. (7) A geyser eruption may be made by constructing a long (two or three feet), narrow tube, filling it with water, and heating it near the bottom until steam is produced.

Reference Books. — RUSSELL, *Volcanoes of North America*, Macmillan Co., N.Y., 1897, $4.00; HEILPRIN, *Mt. Pelée and the Tragedy of Martinique*, Lippincott, Philadelphia, 1903, $3.00; HULL, *Volcanoes*, Scribner's Sons, N.Y., 1892, $1.50; JUDD, *Volcanoes*, Appleton & Co., N.Y., 1881, $2.00; DANA, *Characteristics of Volcanoes*, Dodd, Mead & Co., N.Y., 1891, $5.00; LYELL, *Principles of Geology*, Chapters XXIII–XXV, Appleton & Co., N.Y., 1877, $8.00; BONNEY, *Volcanoes*, Putnam's Sons, N.Y., 1899, $2.00; GEIKIE, *Ancient Volcanoes of Great Britain*, 2 vols., Macmillan Co., N.Y., 1897, $11.25; DUTTON, *Hawaiian Volcanoes*, 4th Annual U. S. Geological Survey, p. 8; GILBERT, *Geology of the Henry Mountains*, Washington, 1877 (out of print); DILLER, *Mt. Shasta*, *National Geographic Monographs*, American Book Co., N.Y., 1895, $2.50; DILLER, *Crater Lake*, Annual Report, Smithsonian Institution, 1897, p. 369; MILNE, *Earthquakes*, Appleton & Co., N.Y., 1891, $1.75; DUTTON, *Charleston Earthquake*, 9th Annual U. S. Geological Survey, p. 209; WEED, *Hot Springs*, 9th Annual U. S. Geological Survey, p. 619.

Fig. 245. — A snow field in the Alps — the top of Mt. Blanc.

Fig. 246. — A névé region in the Alps, showing the slope from which the snow slides, and, in the foreground, the crevassed névé.

FIG. 247. — The Mer de Glace, an Alpine glacier. A band of lateral moraine is seen on the left, and a talus, down which moraine material comes, on the right.

FIG. 248. — Crevasses in a Swiss glacier in the névé region.

Fig. 249. — Snow field and glacier in the Alps with lateral and medial moraines.

Fig. 250. — A valley glacier in Alaska, showing well-defined medial moraine; also the snow field high up in the mountains.

FIG. 251. — The Rhone glacier in Switzerland. This glacier formerly occupied the whole of the valley. Some of its deposits are seen on the left, and the ice-scoured cliffs on the right. The glacier-born stream (the Rhone) is here so embarrassed with sediment that it is aggrading its bed, building a wash deposit (see also Fig. 185).

CHAPTER VIII.

GLACIERS AND THE GLACIAL PERIOD.

99. Valley Glaciers. — The snow line in the Alps is about 9000 feet above sea level. Above this line is a great *snow field* (Fig. 245, 249), in which snow accumulates year after year, in some places reaching a depth of hundreds of feet. Some of the snow is whirled away by the wind, settling in valleys; some slides down the steeper slopes (Fig. 246), as snow slides from the roof of a house. There is so much snow falling into the valleys, both as small slides and great avalanches, that they would be completely filled if it could not in some way be removed.

The snow that accumulates in the valleys gradually changes to granular snow ice, resembling the snow banks of late winter. This change is partly due to the pressure of the overlying mass, and partly to alternate melting and freezing during summer days and nights. The granular ice, called the *névé* (Figs. 246, 248), moves slowly down the steep valleys.

As the mass moves, pressure and further melting and freezing gradually change it to pure, clear ice. The supply from the snow field causes the ice to move down the valley, much as a river extends beyond the place where the rain fell. Such an ice tongue, occupying a valley, is called a *valley glacier* (Figs. 157, 181, 185, 247–251). In the Alps some of the glaciers are 10 to 15 miles long, extending 4000 or 5000 feet below the snow line. They end where the warmth is sufficient to completely melt the ice, and the terminus may be below the timber line, even in the zone where grain will grow.

The glacier moves down grade, behaving much as a mass

of wax does when under pressure; that is, it moves as if it were slowly flowing. The most rapid motion is near the middle, though even here it does not usually move more than two feet a day. Every glacier carries rock fragments, some of which have fallen from the valley sides, while others have been obtained from its bed. These fragments, slowly dragged along, and pressed down by the weight of the ice, groove, striate, and scour the rocks over which the glacier moves. It may be compared to the work of sandpaper. By this scouring, known as *glacial erosion*, valleys are both deepened and broadened.

Bands of rock fragments, accumulated on the margin of the glacier, where they have fallen from the cliffs, are known as *lateral moraines* (Figs. 247, 249). Where two glaciers join, two lateral moraines unite, forming a *medial moraine* (Figs. 249, 250), near the middle of the glacier. The surface of the glacier melts in summer; but moraines protect the ice beneath from melting, and this causes them to stand up as ridges, often 50 feet or more above the surface of the glacier.

Although ice under steady pressure slowly flows, when subjected to a decided strain it breaks, forming cracks, or *crevasses* (Figs. 246, 248), in the glacier. Where the valley bottom is irregular, causing many strains in the moving ice, crevasses are especially abundant; and when the slope of the bottom is steep, the ice may become so crevassed that it is almost impossible to pass over it. Such a section is called an *ice fall.* Moraine fragments are constantly falling into these crevasses, some of them finding their way to the bottom of the glacier. Water from the melting ice also falls into crevasses, boring *pot holes* (p. 54) in the rock floor, and flowing in ice tunnels to the front of the glacier.

The rock fragments frozen in the bottom of a glacier are known as the *ground moraine*, and when a glacier disappears by melting this is left as a deposit on the valley bottom. To it are added the materials of the lateral and medial moraines, which slowly settle to the ground as the glacier melts.

At the end, or terminus, of a glacier, rock fragments are built into a *terminal moraine*. These fragments are brought by the ice and loosened as it melts, accumulating in irregular piles at the base of the glacier front. If the end of a glacier remains in one place for a long time, the terminal moraine hills may reach a height of 100 or 200 feet.

The water that falls into crevasses emerges as a stream from the ice front (Fig. 185), often from an *ice cave*. It is white with suspended sediment, or *rock flour*, supplied by the grinding up of rocks beneath the glacier. In summer, the volume of these glacier streams becomes so great that even pebbles are moved along. The clay is carried far down the valley, but the sand and pebbles are usually deposited on the valley bottom, gradually filling the valley. Over this deposit the stream flows in a branching, braided course, constantly depositing sediment and changing position (Fig. 251). Such *wash deposits* may reach a depth of over 100 feet.

Summary. — *Snow, derived from the snow field, accumulates in the valleys, changing to granular ice (névé), then to ice, which extends down the valley as an ice tongue or valley glacier. As it moves, it scours its bed, and carries rock fragments, both on its surface (lateral and medial moraines) and at its bottom (ground moraine). Both rock fragments and water descend to the bottom of glaciers through crevasses, caused by strains resulting from the ice motion. The rock fragments form a ground moraine and assist the ice in erosion; the water emerges from beneath the ice in streams, bearing rock flour, sand, and pebbles, which build extensive wash deposits. Terminal moraines are built at the ice front.*

100. Glaciers of Alaska. — Of the many Alaskan glaciers the best known is the immense *Muir glacier* (Figs. 253–255), which is fed by twenty glacier tributaries or more. These unite to form an ice tongue which advances down a broad valley and ends in the sea. Its front is a cliff, rising 200 feet above the water and extending 700 or 800 feet below. From it small icebergs frequently break off and float down

the bay. The discharge of icebergs, added to melting, is causing the Muir glacier to steadily grow shorter.

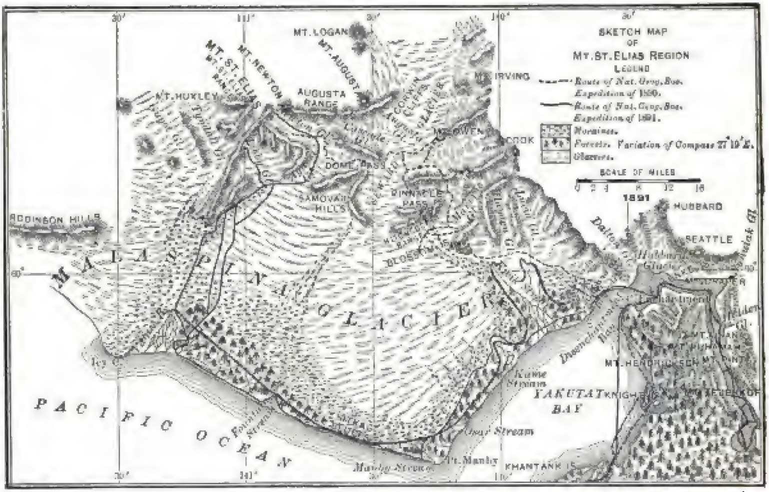


FIG. 252. — The Malaspina glacier.

Farther north is another large glacier, the *Malaspina* (Fig. 252), formed by the union of a number of valley glaciers that descend from the Mt. St. Elias range (Fig. 256). This glacier spreads out, fan-shaped, on a plain at the base of the mountains. For this reason it is called a ***Piedmont*** glacier (from ***pied***, foot, and *mont*, mountain). It has a length of 60 or 70 miles and a breadth of 20 or 25 miles; and its movement is so slow that it is an almost stagnant, undulating ice plateau (Fig. 257).

Melting and evaporation have caused the rock fragments in the upper portion of the glacier to accumulate at the surface, especially near the lower end. These rock fragments form a rocky soil on the glacier, in which a forest is growing (Fig. 258).

Summary. — *Muir glacier, fed by over twenty tributary glaciers, ends in sea cliffs from which icebergs are discharged. Malaspina glacier, an almost stagnant ice plateau, is called a Piedmont glacier.*

FIG. 253. — The sea front of Muir glacier, Alaska.

FIG. 254. — The end of Muir glacier.

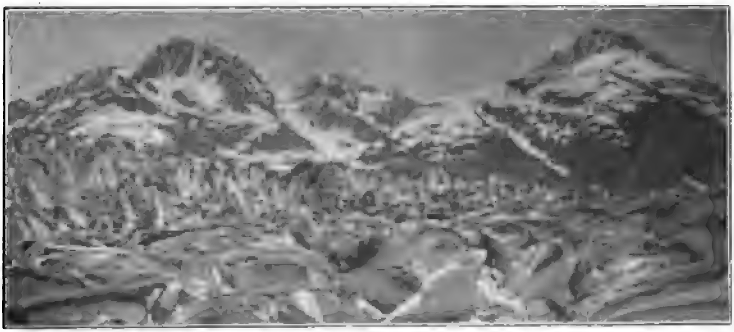


FIG. 255. — The crevassed top of Muir glacier.

FIG. 256. — Mt. St. Elias, Alaska, from which valley glaciers descend to form the Malaspina glacier.

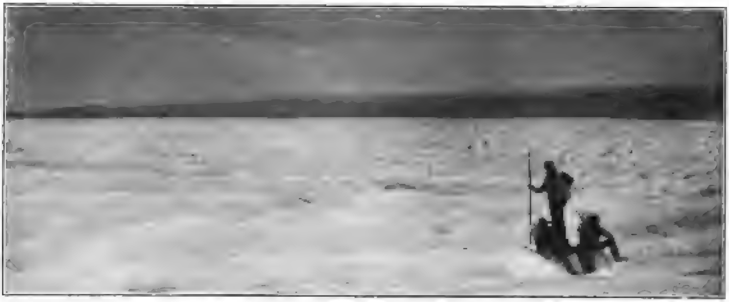


FIG. 257. — The surface of Malaspina glacier, Alaska.

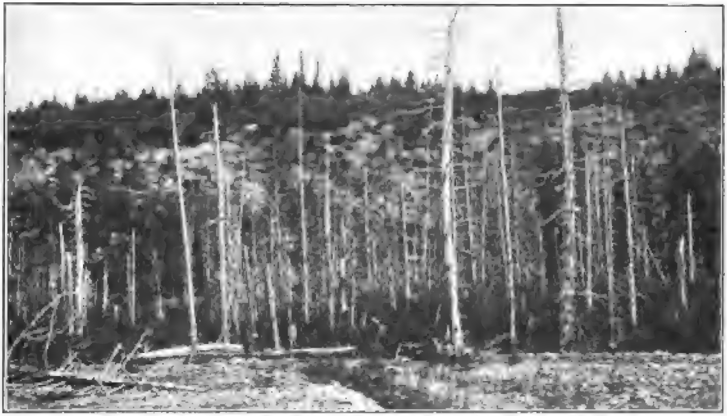


FIG. 258. — Terminus of the Malaspina glacier on the land. This is an ice cliff covered with moraine soil, on the top of which a forest is growing.

101. Distribution of Valley Glaciers. — There are several hundred valley glaciers in Switzerland, and these serve as one of the attractions to tourists. There are also many in the Caucasus and Himalaya mountains, and in Norway, where some descend to the sea.

There are small glaciers in some of the high mountain valleys of Mexico (in the tropical zone) and of western United States. Toward the north glaciers increase in size and number, becoming especially large and abundant in western Canada and Alaska. Tourists are beginning to visit the Selkirk range of western Canada, which rivals Switzerland in the grandeur and beauty of its snow-capped mountains and its glaciers. The Muir glacier is also regularly visited by steamer.

The islands of the Arctic, such as Baffin Land, Iceland, and Spitzbergen, have innumerable valley glaciers, many of which descend to the sea. Glaciers are also abundant in New Zealand and the southern Andes.

Summary. — *Valley glaciers exist in many parts of the world, even in the tropical zone. In cold climates they occupy low valleys, and even descend to the sea; in warm climates they are confined to the upper valleys of high mountains.*

102. Former Extension of Valley Glaciers. — It is well known that valley glaciers were formerly more extensive than at present. In fact, they once existed in places where now there are none. Nearly all Switzerland was once covered by an ice sheet, formed by the union of valley glaciers; there were many in the Rocky Mountains; and glaciers existed even in the Adirondacks and New England mountains.

The clear evidence of this former extension of glaciers is of various kinds, as follows: (1) rock fragments, called *erratics* (Fig. 259), often weighing tons, are found in the valleys. In many cases they are different from the rock near by, but are the same as rock found higher up the valley. They have apparently been brought by some powerful agent, like ice.

(2) The ledges in the valleys have been polished and scratched by the dragging of rock fragments over them

(Fig. 259), as if by ice. These scratches, or *striæ*, extend in the direction in which the erratic *bowlders* have been carried.

(3) Deposits like those now being made by glaciers occur in the valleys (Figs. 251, 260). These include lateral, medial, terminal, and ground moraines, the ground moraine making a thin sheet of mixed clay, pebbles, and bowlders, called *bowlder clay* or *till*. This till is unlike water deposits, being unassorted and unstratified; but it is like deposits from ice, which carries and drops large and small fragments with equal ease, and, therefore, side by side. In front of the terminal moraines, and sometimes mixed with them, are wash deposits of stratified gravels, like those now being laid down by the streams that issue from glaciers.

(4) The valleys also show signs of glacial erosion (Figs. 251, 259, 261, 262). The rocks of their sides and bottoms are polished by ice scouring, and the ledges are worn into smooth, rounded curves, known as *roches moutonnées* (sheep backs). This erosion has often broadened and deepened valleys (Fig. 261); and where they have been deepened a little more than elsewhere, *rock basins* have sometimes been formed, now occupied by lakes and ponds. In some cases the valleys have been deepened hundreds of feet; and in the region of former névé, broad deep amphitheaters, called *cirques*, have been formed.

Since the ice disappeared, side streams tributary to these ice-eroded valleys have not had time to cut their bottoms down to the level of the deepened main valleys. Their bottoms therefore stand above the level of the main valley, and they are accordingly called *hanging valleys* (Fig. 293). From them the streams tumble into the main valley as falls or rapids. These waterfalls add to the charm of the mountain scenery in Switzerland, Norway, Alaska, and other regions from which glaciers have departed.

Summary. — *Erratics, striæ, moraines, till, and wash deposits are among the evidences that valley glaciers were formerly more extensive, and even existed where now there are none. Evidences of ice erosion are also found, in the form of roches moutonnées, broadened and deepened valleys, rock basins, cirques, and hanging valleys.*

FIG. 259. — The top of a Swiss glacier, showing crevasses. Beyond it is a smoothed, scratched rock surface with erratic bowlders on it. The ice has left this surface so recently that vegetation has not had time to occupy it.

FIG. 260. — Moraines and moraine lakelets in a Rocky Mountain valley, in which a valley glacier formerly existed.

Fig. 261. — Lauterbrunnen valley and fall, Switzerland, a valley down which a glacier formerly extended, deepening it.

Fig. 262. — A view on the Grimsel Pass, Switzerland, showing a smoothed rock valley with little lakes. This was formerly occupied by a glacier which has now entirely disappeared, leaving scoured rock sides and moraine deposits as proof of its former existence.

103. The Greenland Ice Sheet. — The island of Greenland is mountainous, not greatly unlike northern New England and Scotland. Near the coast there is a fringe of peninsulas and islands on which there are scattered Eskimo settlements. The mountain valleys have valley glaciers, and small ice caps exist on some of the larger islands and peninsulas.

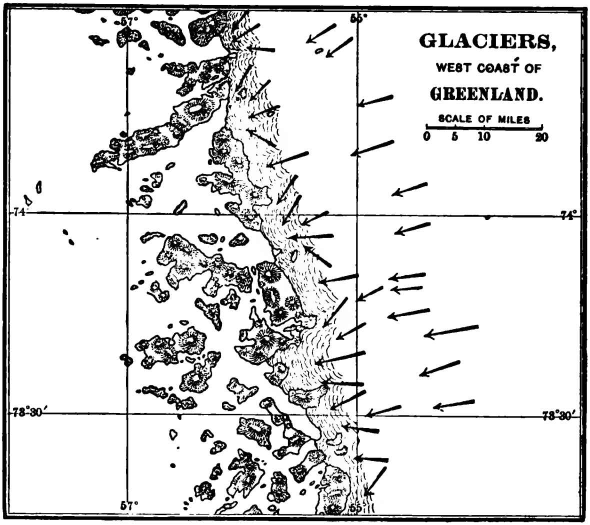


FIG. 263. — A map of the region around the Cornell glacier where Figs. 264, 265, and 271 were taken (near the long peninsula at the top). The arrows show the general movement of the ice, outward from the interior, but turning down into the valleys, and ending in tongues in the bays and fiords.

Back of the fringe of coast land is a great waste of ice and snow, with an area of about 500,000 square miles, more than ten times the area of New York State. This enormous ice cap is sometimes called the Greenland glacier; but it is so large, and, in a number of ways, so different from what is commonly called a glacier, that the term *ice sheet* is a better name. *An ice sheet is a mass of ice, covering and moving over a large area of land, hill and valley alike.*

In the interior, a part of which Peary has crossed, the elevation is 8000 to 10,000 feet, and the temperature never rises above the freezing point. The surface is, therefore, always covered with loose, dry snow. Nearer the coast, where the elevation is less, the warmth of the summer sun melts the snow, leaving an ice surface quite like that of valley glaciers.

The continued fall of snow on the high interior of Greenland has caused such an accumulation that, changed to ice by pressure, it is forced to move slowly outward (Fig. 263) in all directions, — north, east, south, and west. It moves as a great pile of wax would, and in its slow, irresistible outward movement crosses hill and valley alike.

Back of the coastal fringe the only land that appears is an occasional high mountain peak, called a *nunatak* (Fig. 264), which projects like an island above the sea of ice. Near the coast the ice extends down the valleys, often reaching the sea (Figs. 263, 264). At the head of fiords these valley tongues end in sea cliffs 200 or 300 feet high (Fig. 265), advancing in some cases at the rate of from 50 to 75 feet a day, and discharging huge icebergs that float into the Arctic (Figs. 267, 268, 339). Most of these tongues are only a few miles wide; but the largest of all, the Humboldt glacier of north Greenland, is 60 miles wide. Their surface is broken by crevasses, quite unlike the smooth, unbroken ice plateau of the interior.

Unlike that of valley glaciers, the surface of the ice sheet is quite free from rock fragments, excepting where nunataks supply materials for a medial moraine, or, near the end of a valley tongue, where cliffs rise from the ice margin. Near the bottom, however, there is much rock material, which has been worn from the land. In transporting this load of rock fragments at its base, the ice sheet scours its bed and does much work of erosion.

Melting near the margin causes streams and even ponds

FIG. 264. — A view of the Greenland ice sheet, showing its vast expanse, its extension into the fiord valleys, and a nunatak rising above its surface. This is a view of the Cornell glacier, one of the large valley tongues of the Greenland ice sheet.

FIG. 265. — Front of the Cornell glacier (Fig. 264), where it advances into the fiord. From it huge icebergs are frequently discharged.

FIG. 266. — A wash plain deposit made by water at the margin of a Greenland glacier. (Compare with Figs. 272 and 275.)

FIG. 267. — An iceberg aground near Fig. 264.

FIG. 268. — A tunnel in Fig. 267, perhaps an old stream channel in the ice.

to form on top of the ice; and this water finds its way by crevasses to the bottom. Where this water emerges, either on the land or in the sea, deposits of gravel and clay are being made (Figs. 266, 272). Along the ice front, too, moraines are being built of rock fragments loosened by melting (Fig. 271). Many of these are worn and scratched (Fig. 290) by the grinding they have received.

There is good evidence that the Greenland ice sheet, like valley glaciers, once extended much farther, completely covering some, if not all, of the islands and peninsulas. This evidence is supplied by moraines, erratics, glacial scratches, rounded and deepened valleys, and rock basins. The Greenland ice sheet, like the Muir and many other glaciers, is now melting back.

Summary. — *Greenland is covered by a great ice sheet, with a fringe of land near the coast, and, near the margin, occasional nunataks projecting above the ice. From the high interior, where snow falls summer and winter, there is a movement outward in all directions, the margin of the ice consisting of valley tongues, often ending in the sea into which icebergs are discharged. The ice has little rock material on the surface, but carries much near the bottom, with which it is doing work of erosion and making moraine and wash deposits.*

104. Other Ice Sheets. — On the Antarctic continent there is an enormous ice sheet, of which little is known. It is generally believed that the entire South Polar region is covered by an ice cap, with an area larger than the United States. For a long distance its margin is a great ice wall, rising several hundred feet above the sea and discharging huge tabular icebergs.

On the larger islands of the Arctic there are also ice caps, resembling that of Greenland, though smaller. There is evidence that ice sheets once spread completely over these islands.

Summary. — *There is a great ice sheet on the Antarctic continent, and smaller sheets on some of the larger islands of the Arctic.*

105. Formation of Icebergs. — When a glacier enters the sea the water buoys the ice up, causing great masses to break off, forming icebergs (Figs. 265, 267, 268, 339). Other masses are broken away by undercutting along the water's edge. As the icebergs

drift slowly away, they melt, strewing rock fragments along the sea bottom. They often run aground (Fig. 267), pushing and grinding the layers of sediment on the bottom.

It is fortunate that the icebergs drift *away* from the glacier, otherwise the fiords would soon become choked with berg ice. They float away in an outward current of water caused by winds from the ice sheet and by fresh water from the melting ice.

Summary. — *Icebergs are discharged* (1) *by undercutting along the water's edge, and* (2) *by buoying up of ice as it advances into the sea.*

106. Former Ice Sheets in Europe and America. — There is good evidence that, not many thousand years ago, a great ice sheet spread over northeastern America (Fig. 270), and another over northwestern Europe. Scandinavia, Denmark, northern Germany, northwestern Russia, and all of the British Isles, excepting southern England, were then covered by ice. Canada east of the Rocky Mountains, New England, northern New Jersey, nearly all of New York, northern Pennsylvania, much of Ohio, and the states farther west and northwest, as far as Montana, were also ice-covered. These ice sheets, which were quite like those now covering Greenland and the Antarctic continent, have been called *continental glaciers.*

The proofs of these former ice sheets are of the same kind as those of former greater extension of valley glaciers (p. 141) and of the Greenland glacier (p. 145). These proofs include glacial scratches (Figs. 289, 291), glacial pot holes, and erratic bowlders (Fig. 285). The scratches point toward the north, and many of the bowlders can be traced to a northern source, some in the United States having come from Canada. There is also evidence of ice erosion and valley deepening; and there are lakes in rock basins that the ice scoured out (p. 153). Where the ice stood, the land is covered by a sheet of ground moraine, and there are bands of terminal moraine (Fig. 274), with wash deposits in front (Fig. 275). These glacial deposits were called *drift*, because they were thought to

have been brought, or drifted, by great floods of water; and the term *glacial drift* is still applied to them.

Louis Agassiz, in the middle of the last century, first proposed the glacial theory to account for this drift. Being a Swiss, he had studied glaciers in Switzerland, and had seen the clear evidence (p. 141) that Alpine glaciers were formerly more extensive. He saw that the same evidence was present in the British Isles and in America, and proposed the theory that there had been a *Glacial Period.* This at first met a storm of opposition, but is now accepted by every one who has studied the question intelligently.

Summary. — *Striæ, erratics, evidences of erosion, moraines, etc., prove that great continental glaciers, or ice sheets, formerly covered northeastern America and northwestern Europe. Louis Agassiz proposed the now accepted explanation of the Glacial Period.*

107. Cause of the Glacial Period. — Why there should have been a glacial climate in temperate latitudes is not positively known. At present the climate of Labrador, Scandinavia, and other centers from which the ice spread, is very cold; and, if they were elevated several hundred feet, great ice caps might slowly gather on them and spread out into lower and warmer regions. Before the Glacial Period these lands actually were higher than now, and one theory is that this former elevation caused great ice sheets to form and move down into the United States and Europe. In the United States an ice sheet from Labrador joined forces with ice sheets from the Adirondack and New England mountains, and spread over hill and valley, advancing slowly and irresistibly, as the ice sheet of Greenland does. It advanced southward to a zone where melting became so great that it could go no farther.

After many thousand years the climate gradually changed, perhaps because the land was lowered. Then the ice front slowly melted back, or "retreated." We do not know how long ago the ice melted away, but there is evidence pointing to from 5000 to 10,000 years (p. 333). The time since the ice left is so short, however, that the drift deposits are still quite fresh; and even delicate striæ remain (Fig. 289) wherever protected by a thin coating of soil (p. 41).

Summary. — *One theory for the Glacial Period is that when the land was higher in Labrador and Scandinavia, ice caps formed and spread out in all directions, and, after many thousand years, when the land was lowered, melted away.*

108. Terminal Moraines. — While the ice sheet was melting back there were periods when it halted for a time and built terminal moraines (Fig. 274). These bands of moraine, which resemble those now forming at the margin of glaciers, may be easily traced. They consist of irregular, hummocky hills, varying from a few feet to 100 or 200 feet in height, and inclosing many basins, or *kettles*, often occupied by ponds. The moraines are made partly of till, and partly of stratified drift deposited by water from the melting ice.

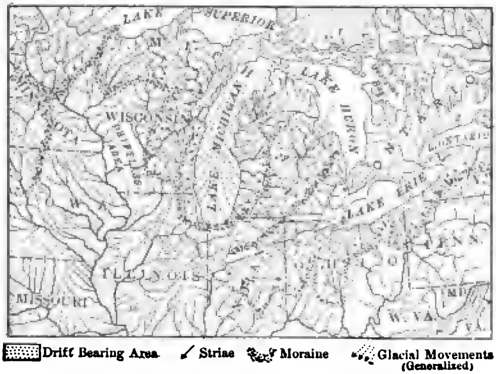


Fig. 269. — Lobate moraines in the Central States, showing the influence of the Great Lakes valleys in causing the ice tongues to extend farther south.

Ice tongues, or *lobes*, extended farther in the valleys than on the hills, and on this account the moraines bend southward in the valleys, forming looped or *lobate moraines* (Figs. 269, 273). Terminal moraines were built at each halt of the receding ice sheet, and they are called *moraines of recession* (Fig. 273).

Summary. — *At each halt of the receding ice sheet a terminal moraine was built with lobes extending down the valleys. These moraines are low, hummocky hills, with inclosed basins, or kettles, often occupied by ponds.*

FIG. 270. — The ice sheet in eastern United States. (Photograph of a model made by E. E. Howell, Washington.)

FIG. 271. — Edge of the Greenland ice sheet on the land (near Fig. 264). The dark layers of ice are due to rock fragments, and the ridge in the foreground is a moraine built by the falling of these from the ice margin.

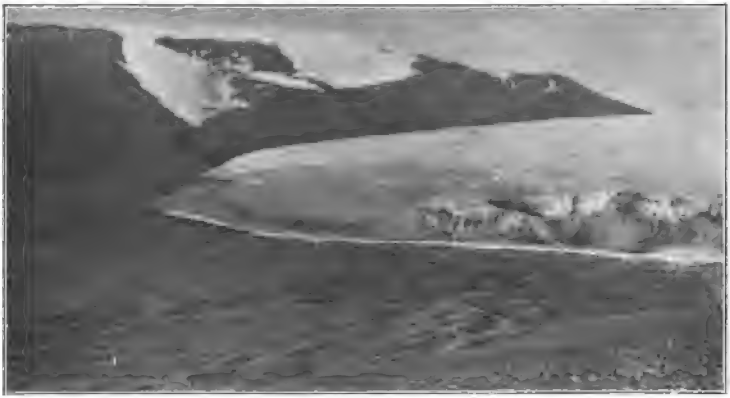


FIG. 272. — A stream extending from a Greenland ice tongue and flowing in braided course over a wash plain which it is building up (see also Fig. 266).

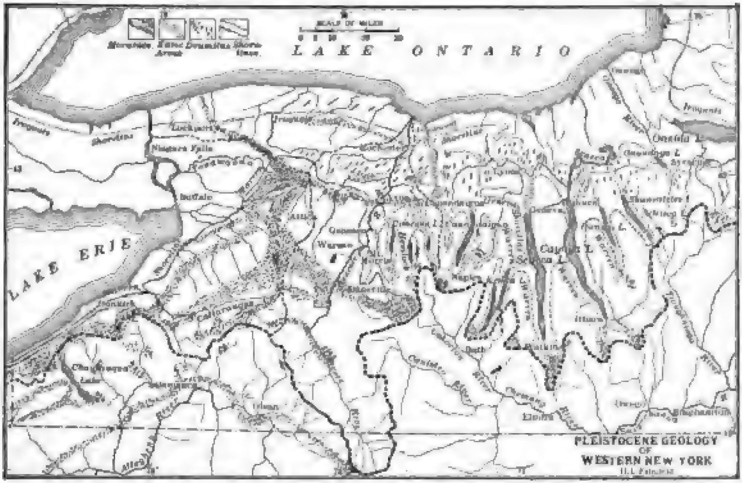


Fig. 273. — The lobate moraines of recession in western New York. The outermost terminal moraine is the one that bends up from Pennsylvania to Salamanca and Olean. Also location of drumlins, and of shore lines of glacial lakes. The heavy line is the divide. The lakes have all been caused by glacial action.

Fig. 274. — Photograph in the terminal moraine near Ithaca, N.Y. Notice how hummocky the surface is; this is characteristic of moraines.

FIG. 275. — A wash plain near Fig. 274, deposited by a stream flowing from the glacier when the moraine was being built. Compare Figs. 251, 266, and 272.

FIG. 276. — A kame near Fig. 275. It is made entirely of stratified gravel, and in the center, just above the tree to the right of the horse, has a very deep kettle hole that looks like a crater.

109. Stratified Drift. — Water issuing from the melting glacier built several classes of deposits. All these are stratified, because water assorts rock fragments (p. 32). These stratified deposits are called *stratified drift.* Of these the most extensive are the *wash plains* (Fig. 275), which resemble those now forming in the Swiss valleys (p. 139). Many valleys in eastern America are filled to a depth of from 100 to 300 feet with these level, gravelly plains, built by ancient glacial streams. Wherever the ice front rested on fairly level land the glacial streams built a series of low, flat alluvial fans. The plains on the south side of Long Island are of this origin.

At and under the ice front the water built irregular, hummocky hills of gravel, called *kames* (Fig. 276), in which deep basins, or kettles, are often found. Some of the kames were apparently made by streams, bearing much gravel, which tumbled to the bottom of the glacier through crevasses. This gravel occasionally covered blocks of ice which, on melting, allowed the gravel to settle, forming the kettle holes.

Long, narrow ridges of gravel, sometimes miles in length, and with an irregular, serpentine course, are called *eskers* (Fig. 282). These are the gravel beds of streams that flowed in tunnels or gorges in the ice, usually at the bottom. Where these streams emerged from their ice tunnels they built wash plains; or, if the end was in small, ice-dammed lakes, they built deltas. These level-topped deltas are called *sand plains.*

Summary. — *Water from the melting ice made stratified deposits: kames where streams tumbled to the base of the ice; eskers where they flowed in ice tunnels; wash plains where they emerged upon the land; and sand plains in small, ice-dammed lakes.*

110. Ice-dammed Lakes. — In some places the ice front stood in large lakes (Figs. 278, 279), formed where north-flowing streams were dammed by the ice. Clay and gravel deposits were made in these, and along their shores deltas and beaches were built.

One of these large lakes was formed in the valley of the Red River of the North (p. 78). Other north-flowing streams were dammed by the ice, some of the valleys having small, others large, glacial lakes. The case of the Great Lakes is especially interesting. At first a few small lakes were formed, one outflowing past Chicago, one past Duluth, and one past Fort Wayne, Ind. (Fig. 280). As the ice melted back these grew larger, uniting with an outflow past Chicago (Fig. 280). Then an enormous volume of water, comparable to Niagara, escaped into the Illinois River. The small lake harbor around which Chicago has grown up was scoured out by this outflow. As the ice continued to melt back, a still lower outlet was opened eastward through the Mohawk valley (Figs. 277, 280), the Chicago outlet was abandoned, and for a while the glacial lakes outflowed into the Hudson past Little Falls, N.Y. Finally, when the ice disappeared from the St. Lawrence valley, the present course was established.

Fig. 277. — **The Ontario region during the stage of outflow through the Mohawk (Fig. 280; see also Fig. 273).**

The beaches that were formed at the levels of the different outlets of these various lakes may still be clearly seen. For example, the beach ridge from Syracuse to Lewiston (Fig. 273), on which the "ridge road" is built, was recognized as a beach by the early explorers. The fine-grained clay that was deposited on these lake bottoms makes a level, fertile soil. Consequently, the region between the elevated beaches

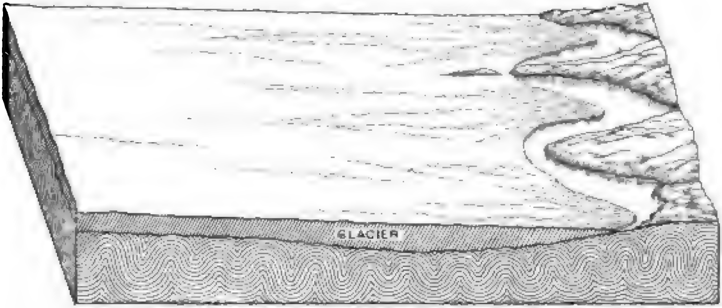


FIG. 278. — Diagram of an ice sheet on an irregular land, damming up a series of lakes along its margin. Describe what you see.

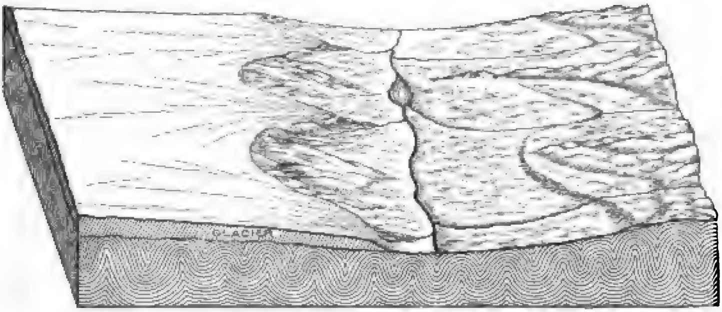


FIG. 279. — The same as Fig. 278 with the ice melted back somewhat, uncovering a valley which it had crossed. A moraine marks the former position of the ice front in the glacial lake. Describe what you see in this.

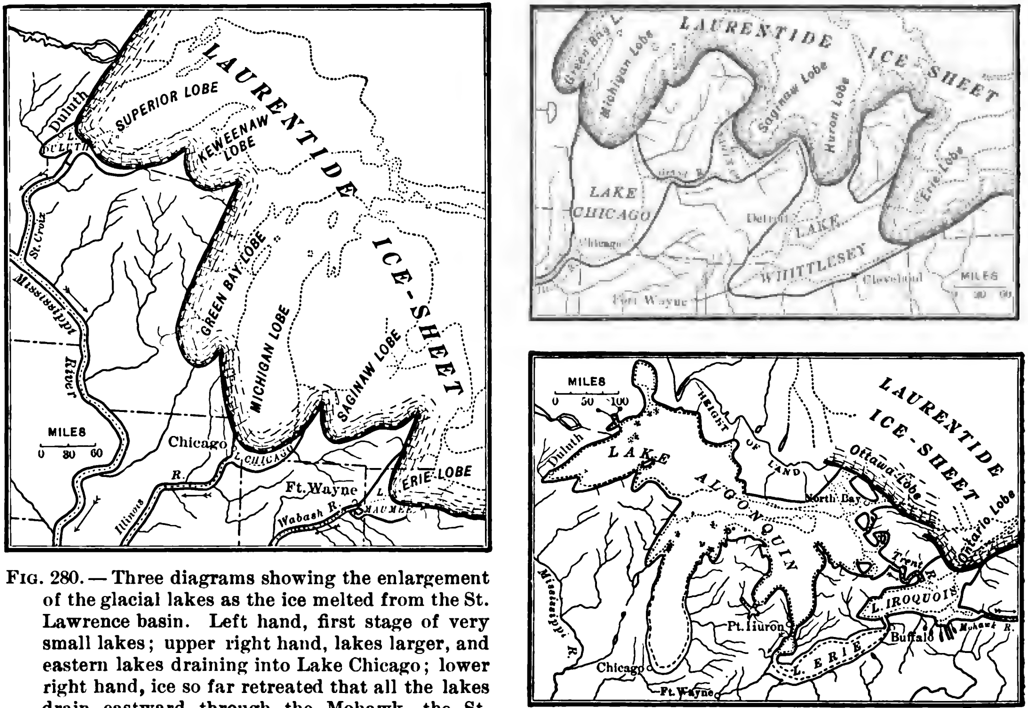


FIG. 280. — Three diagrams showing the enlargement of the glacial lakes as the ice melted from the St. Lawrence basin. Left hand, first stage of very small lakes; upper right hand, lakes larger, and eastern lakes draining into Lake Chicago; lower right hand, ice so far retreated that all the lakes drain eastward through the Mohawk, the St. Lawrence being still ice-filled. The upper lakes then flowed through the Trent river, because the land in the north was then so low that the Detroit channel could not be occupied. The dotted lines in Lake Erie and southern Lake Michigan represent the outline of the lakes at this stage, when the land was so low in the north that the water did not completely fill these basins. Elsewhere the ice dam forced the water to rise beyond the margins of the present lakes.

and the present lake shores is the seat of prosperous farms, orchards, and vineyards.

The beaches are not horizontal, but rise toward the northeast at the rate of about three to five feet a mile; and this is taken as proof that the land has been tilted since they were formed. As a result of this tilting, the lakes have changed from one outlet to another (Figs. 280 and 281).

Uplift of the land is still in progress at a very slow rate, and if it continues, the upper Great Lakes will eventually abandon the Detroit channel and once more outflow past Chicago. At the present rate of tilting the water will begin to spill over the Chicago rim in 500 or 600 years; and in 3500 years Niagara will be changed to a very small stream.

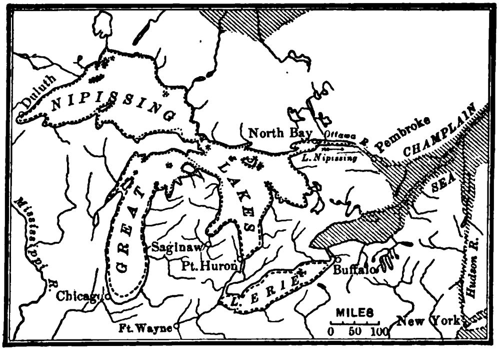


FIG. 281. — After the ice had entirely left the St. Lawrence valley, the land in the north was so low that the sea (shaded) entered the Champlain and Ontario basins, and the upper Great Lakes outflowed through the Ottawa River. Then Niagara carried the water only of Lake Erie. As the land in the north rose, the upper lakes were tilted until they finally overflowed past Detroit.

Summary. — *As the ice was melting from the land it dammed north-flowing streams, causing temporary glacial lakes which disappeared when the ice dam melted away. Lakes of this sort were formed in the valleys of the Great Lakes, shifting their outlets as lower ones were uncovered by ice melting, or made possible by land tilting. The tilting of the land is still in progress.*

111. Loess. — In central United States there is a sheet of fine-textured clay known as *loess*, a German name for a similar deposit in that country. Some of the loess was evidently drifted by winds, and some of it was brought from the ice front in slowly

moving sheets of water. In China there is an extensive deposit of loess brought by the wind.

Summary. — *Loess is a fine-textured clay, in some cases wind-deposited, in others brought by slowly moving sheets of water.*

112. The Till Sheet. — The principal soil of a glaciated country is *till* or *bowlder clay*, which occupies the region between the moraines, wherever the surface is not covered by stratified drift. Till is a compact clay, usually unstratified, with bowlders and pebbles mixed through it (Fig. 283). It is the ground moraine left when the ice melted.

The till sheet varies greatly in thickness, being usually thin where the rock is hard, and thick where it is soft and easily ground up. In Labrador, and in hilly New England, there are large areas with little or no till; but in the Mississippi valley, where the land is more level and the rock softer, the till sheet is sometimes 100 or 200 feet thick.

There is also much difference in composition. In some places it is made of clay with only occasional bowlders; in others it is so full of bowlders that farming is almost impossible (Fig. 284). An abundance of bowlders is liable to be found just south of mountain areas of hard rock, as in New England, and south of the Adirondacks. They sometimes form trails, or *bowlder trains*, from the place of origin, growing less common and smaller as the distance from the source increases, because of the erosion to which they have been subjected. In central New York, where the bowlders are largely hard rock from the north, farmers call them "hardheads."

Summary. — *Till or bowlder clay, the most widespread glacial deposit, is the ground moraine. It is a sheet of mixed clay and bowlders varying in thickness and in the proportion of bowlders.*

113. Drumlins. — In many sections the till sheet is smooth and regular, covering the surface to a fairly even depth; in other places it is ridged and irregular. One peculiar irregularity of till is the *drumlin* (Figs. 286–288). Drumlins vary from 100 feet to

Fig. 282. — An esker ridge near Ithaca, N.Y. This is a stream deposit made in a tunnel underneath the glacier.

Fig. 283. — A section in till in which there are not many bowlders.

Fig. 284. — A bowlder-strewn, glacial soil in Maine.

Fig. 285. — Large glacial bowlders brought by the ice.

Fig. 286. — A drumlin at Ipswich, Mass.

Fig. 287. — A drumlin north of Auburn, N.Y.

Fig. 288. — A part of the United States Geological Survey Topographic Map (Watertown, Wis., Sheet), showing a large number of drumlins. Also notice how the drift has embarrassed the streams, causing them to take long, roundabout courses, and transforming their valleys to swamps in many places.

FIG. 289. — The end of the hammer handle rests on a glacial scratch or groove on a ledge of shale rock.

FIG. 290. — A pebble with glacial scratches; taken from the Greenland ice sheet at the place shown in Fig. 271.

FIG. 291. — A pebble with glacial scratches; taken from a till bed at Ithaca, N.Y.

a mile or more in length, and from 20 to 100 or 200 feet in height. Some are long and ridge-like; some short and lumpy; but the most typical drumlins are oval, having the shape of a half-submerged egg (Fig. 286), with the long direction parallel to the water surface. They are masses of till ridged up under the ice.

Drumlins usually occur in clusters. There is one group in Wisconsin, near Madison (Fig. 288); another in central New York between Rochester and Syracuse, and northward to Lake Ontario (Fig. 273, 287); another in the Connecticut valley; another in and near Boston (Fig. 286). Boston is built on drumlins, of which Bunker Hill is one.

Summary. — *Elongated ridges of till, usually in clusters, are called drumlins. They vary greatly in shape and size, the most perfect having the oval shape of a half egg.*

114. Glacial Erosion. — In a glaciated country wherever the rock is uncovered, its surface is liable to be polished, scratched, and grooved (Fig. 289). In eastern United States the striæ point toward Labrador. Striæ and erratics found on high mountains prove that the ice was thick enough to override the tops of mountains even a mile in height.

The northern slopes of hills and mountains over which the ice moved are often rounded by ice erosion; and ledges have the smoothed and rounded form of the roches moutonnées (p. 142). Pebbles and bowlders in the till are also smoothed and scratched (Fig. 291). It is evident, therefore, that much work of erosion was done as the ice sheet moved onward, pressing down with enormous weight, and dragging its rock load over the land. It acted like a great rasp or sandpaper.

By this erosion some rock was removed from the hills, but more was worn from those valleys along which the ice moved freely. In this way many north-south valleys were so deepened that their tributaries now enter through hanging valleys (Fig. 293); and the same is true of bays and fiords on the coasts of Maine, Labrador, Alaska, and Norway. By such erosion the valleys of the larger Finger Lakes of central New York (Cayuga and Seneca) were

deepened; and part of the depth of Lake Ontario, and others of the Great Lakes, is also due to ice erosion. During this erosion, rock basins, in which lakes and ponds now stand, were scoured out. Thus the land surface was decidedly modified by erosion.

Summary. — *That the ice sheet did much erosion, is proved by striated pebbles, bowlders, and ledges ; by rounded north slopes ; by roches moutonnées ; by hanging valleys; and by rock basins. The ice sheet acted like a great rasp, planing down the surface, especially in valleys through which it freely moved.*

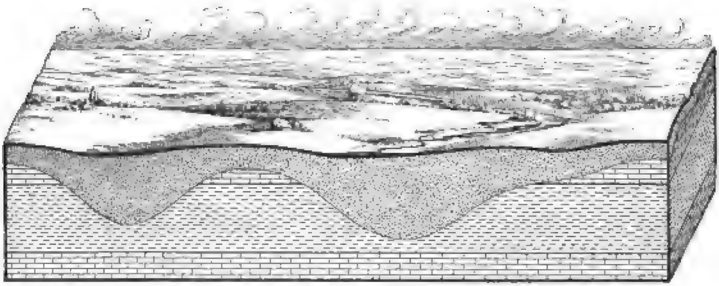


FIG. 292. — To illustrate the effect of glacial deposits (dotted) in leveling a hilly country by filling the valleys, as in the prairie region of the Central States.

115. Effects of the Ice Sheet. — In some places the surface was roughened by the deposit of drumlins, eskers, kames, and moraines. Elsewhere the drift has smoothed the surface by making thicker deposits in the valleys than on the hills. This smoothing reaches its extreme in the prairie region of the Central States, where, in some cases, drift in the valleys has a depth of 500 feet. The level surface and fertile soil of the prairie is, therefore, due to the glacier (Fig. 292).

Throughout the glacial belt the drift soil shows many variations; for example, stony, clayey, sandy, gravelly, level, irregular. On a single farm there may be several kinds of soil. Sometimes this is better than the soil of rock decay that existed before the ice sheet came; in other cases a barren, sandy, gravelly, or bowldery soil (Fig. 284) has been left in

FIG. 293. — A hanging valley in the Engadine, Switzerland. The lake (the Silsersee) is in the Engadine valley. The rock bottom of the tributary valley, on the opposite side, is some distance above the main valley. It is, therefore, a hanging valley. The stream in the hanging valley has cut a gorge in its bottom and built a delta in the lake.

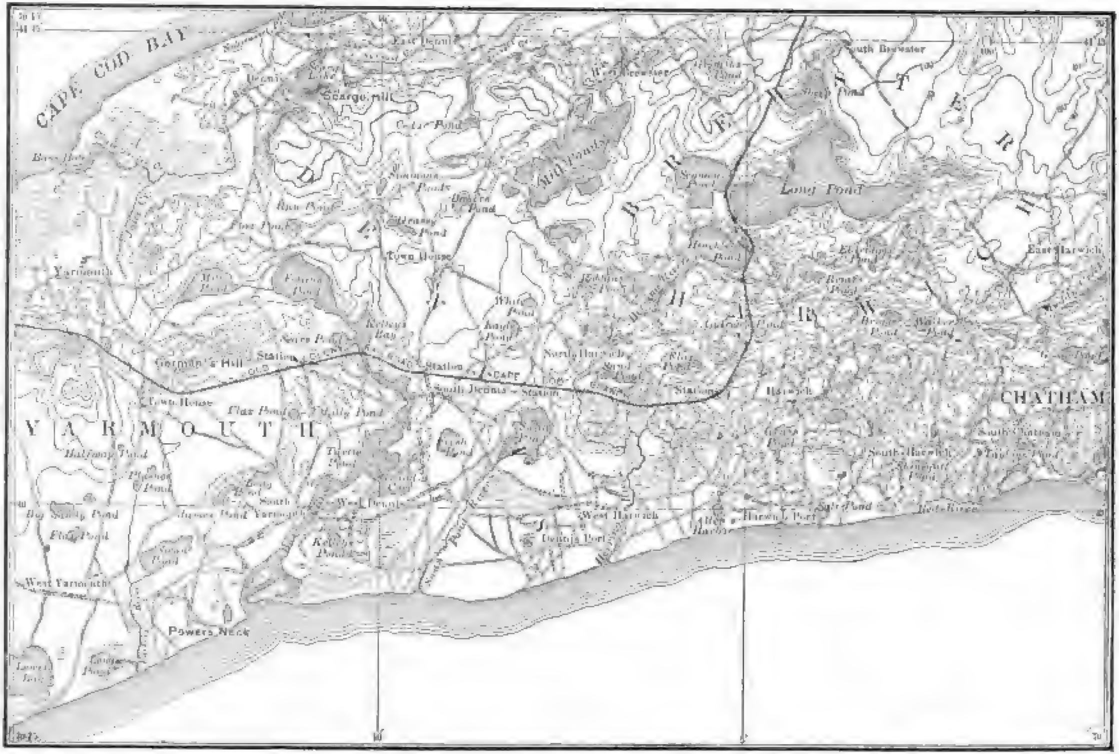


FIG. 294. — Large numbers of ponds in the Cape Cod terminal moraine. The contour lines show the hummocky nature of the moraine. (Yarmouth, Mass., Topographic Sheet, United States Geological Survey.)

place of a fertile residual soil. Usually the glacial soil is a strong one, because it consists of ground-up rock fragments, which are slowly decaying and releasing plant food.

The sheet of drift has turned many streams aside, causing them to cut new valleys for a part of their course. In these the streams have often reached the rock and cut post-glacial gorges, in which there are rapids and falls (Figs. 60, 67, 71, 75). There are thousands of instances of this, and many of the falls are of great value for water power; for instance, the falls in the Mississippi at Minneapolis, Niagara, the falls at Rochester, and the rapids in the Merrimac where Manchester, Lawrence, and Lowell are situated. South of the glacial belt there are few places where there is water power; but in New England, New York, and other states in the glacial belt, it is this water power that has given rise to so much manufacturing.

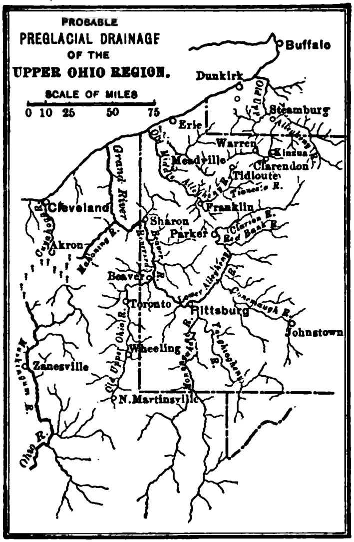


FIG. 295. — Compare this map with one of the present drainage. For purpose of comparison, make a sketch map of the present drainage from a geography map.

In some cases streams have been turned into other river systems. Before the glacial period the upper Ohio, above Wheeling (Fig. 295), flowed into Lake Erie valley through the Grand River; and the Allegheny is made by the union of two streams, one of which entered the Lake Erie valley west of Erie, Pa., the other east of Dunkirk, N.Y. The present St. Lawrence system has also been made by the union of several independent parts.

Could we restore the pre-glacial drainage of the United States,

it would, in thousands of cases, be found different from the present. Some of these changes have been of great importance; for example, how different would have been the history of Pittsburg if there had been a waterway to the north (Fig. 295) instead of to the southwest! How different would have been the history of Cincinnati if the Ohio flowed past it as a small stream without its great tributaries, the Allegheny and Monongahela! And what a contrast there would be where Buffalo and the other lake cities stand if glacial changes had not united streams and caused lakes in the valleys of the St. Lawrence system!

Of the tens of thousands of lakes in the glacial region, the great majority are due to some interference of drift deposits with drainage (Figs. 297–300). This is true of the small ponds and lakes, of which there are said to be 10,000 in Minnesota alone; and it is true of the many large lakes. Even the basins of the Great Lakes, caused in part by glacial erosion and changes in level of the land, owe a portion of their depth to dams of glacial drift. What an important difference it would make in the cities and industries of northern United States if glacial action had not caused the lakes which dot the surface!

Summary. — *The ice sheet caused many changes, making some regions rougher than before, others smoother; it changed the soil, causing it to differ greatly from place to place; by turning streams aside, it led to the formation of many gorges and waterfalls; it has even turned streams into other systems; and it has made thousands of lakes, great and small.*

Topical Outline, Questions, and Suggestions.

Topical Outline. — 99. **Valley Glaciers.** — (*a*) Formation: snow field; movement of snow; névé; formation of ice; extension of ice tongue. (*b*) Movement: nature; rate; glacial erosion. (*c*) Moraines: lateral; medial; crevasses; ice falls; movement of materials to bottom; ground moraine; terminal moraine. (*d*) Wash deposits: source of water; of sediment; rock flour; nature of deposit.

100. **Glaciers of Alaska.** — (*a*) Muir: tributaries; front; withdrawal. (*b*) Malaspina: form; size; movement; surface condition.

101. **Distribution of Valley Glaciers.** — Europe; North America, — Mexico, United States, Canada, Alaska; Arctic; southern hemisphere.

102. **Former Extension of Valley Glaciers.** — (*a*) Instances. (*b*) Evidence: erratics; striæ; moraines; till; wash deposits. (*c*) Ice erosion: roches moutonnées; rock basins; cirques; hanging valleys.

103. **The Greenland Ice Sheet.** — (*a*) General condition: topography; coast; valley glaciers; area of ice; meaning of ice sheet. (*b*) The ice sheet: interior condition; outward motion; nunataks; valley tongues; size; movement; icebergs. (*c*) Rock materials: on the surface; at the base; erosion; deposits at margin. (*d*) Former extension.

104. **Other Ice Sheets.** — Antarctic; islands of Arctic.

105. **Formation of Icebergs.** — Causes; effects; outward movement.

106. **Former Ice Sheets in Europe and America.** — (*a*) Extent: Europe; America; continental glaciers. (*b*) Proofs: striæ; erratics; ice erosion; glacial deposits; glacial drift. (*c*) Agassiz's explanation.

107. **Cause of the Glacial Period.** — Land formerly higher; probable result; retreat of ice; time since ice withdrawal.

108. **Terminal Moraines.** — Cause; form, size, kettles; composition; lobate moraines; moraines of recession.

109. **Stratified Drift.** — Nature of stratified drift; wash plains; kames; kettles; eskers; sand plains.

110. **Ice-dammed Lakes.** — Cause; Great Lakes, — early stages, changes in outflow, beaches, lake clays; changes of level, — evidence, effect on outflow, present changes.

111. **Loess.** — Nature; occurrence; cause.

112. **The Till Sheet.** — Distribution; nature of material; variation in thickness; variation in bowlders; reason for variation; bowlder trains.

113. **Drumlins.** — Size; shape; cause; occurrence.

114. **Glacial Erosion.** — Striæ; north slopes; roches moutonnées; scratched pebbles; nature of the ice erosion; effect in valleys; illustrations; rock basins.

115. **Effects of the Ice Sheet.** — (*a*) On the land surface: irregular surfaces; smooth surfaces; prairies. (*b*) On soil: differences; strength of glacial soils. (*c*) On streams: formation of gorges and falls; instances; effect on manufacturing; complete turning aside of streams; importance of this. (*e*) On lakes: cause; numbers; Great Lakes; importance.

Questions. — 99. What is the snow field? What is the nature and origin of the névé? What is a valley glacier? Why does it extend down the valley? How does the ice move? What is happening at its bottom? What are lateral moraines? Medial moraines? Crevasses? Ice falls? What descends through the crevasses? What is the ground moraine? Terminal moraine? Account for the wash deposits.

100. Describe the Muir glacier. The Malaspina glacier.

101. Where are the glaciers found? In what zones?

102. Where did valley glaciers formerly exist? What are erratics? What is till? Why is it unstratified? What work of erosion did ancient glaciers perform? What are roches moutonnées? Rock basins? Hanging valleys? State the evidences of former valley glaciers.

103. What is the condition of Greenland? What is an ice sheet? What is the condition in the interior? How does the ice sheet move? What is the condition at its margin? How are rock materials carried? What deposits are being made? State the evidence of former extension.

104. Where else are ice sheets found?

105. What are the causes for icebergs? Why do they drift away?

106. Where were there former great ice sheets? What evidence is there of former glaciation? Why are the deposits called glacial drift? Who proposed the theory of the Glacial Period? Why?

107. What is the most probable explanation of the glacial period? How did the ice advance? Why did it retreat?

108. What are the characteristics of terminal moraines? What are lobate moraines? Moraines of recession?

109. What is the cause of stratified drift? What are the following: wash plains, kames, kettles, eskers, sand plains?

110. What changes occurred as the ice melted from the Great Lakes? What deposits were made? What evidence is there of change in level of the land? State the past and possible future effects.

111. What is loess? How formed? Where found?

112. What is the principal soil of the glacial region? Where is it found? How does it vary? Why?

113. What are drumlins? How do they vary? Where found?

114. What proofs of glacial erosion are there? What were its effects on the valleys? Give illustrations.

115. What effects had the ice sheet on surface features of the land? On soil? On stream courses? Give instances of streams turned into other systems. What effect had the ice on lakes?

Suggestions. — (1) Cut out a square block of ice and float it in water. Measure it to see what proportion is above water. Place the same block in salt water and measure the proportion above water. (2) In a box, the end of which can be removed, place thin layers of snow interspersed with sheets of mixed gravel, sand, and clay, placing a much greater amount in the part from which the end of the box is to be removed. Compact it as tightly as possible, then allow it to freeze. Remove the end of the box, allow the ice to melt, and watch the result. Does a moraine-like accumulation form at the front? Does the surface of

the ice eventually become covered with sand? A large number of glacial phenomena can be imitated by a little ingenuity, — for example, cutting crevasses, boring a tunnel at the bottom of the ice, and sprinkling the ice surface to supply water. The stream that issues from the tunnel may be made to build wash deposits on a moderate slope; or to build sand plains in temporary lakes along the ice margin, etc. (3) Imitate moraine topography by dumping small pailfuls of sand in piles close together. (4) Is your home in the glacial belt? If so, what effects of the glacier can you find in the neighborhood, either by a study of the topographic map or, better still, on a field excursion? Is the soil till or stratified drift? To answer this question look for cuts and study them carefully. If till, look for scratched stones. If stratified, why are the pebbles rounded and the scratches gone? Look for glacial scratches on recently uncovered exposures of bed rock. What is their direction? Are the bowlders and pebbles all of the same kind as the bed rock? Do you know if any of them could have come from ledges in the direction in which the striæ point? Can you find moraines, kames, eskers, or drumlins? If so, study them, — their form and the nature of the material.

Reference Books. — RUSSELL, *Glaciers of North America*, Ginn & Co., Boston, 1897, $1.75; TARR, *Physical Geography of New York State*, Chapters IV and VIII, Macmillan Co., N.Y., 1902, $3.50; WRIGHT, *Ice Age in North America*, Appleton & Co., N.Y., 4th ed., 1902, $5.00; *Man and the Glacial Period*, Appleton & Co., N.Y., 1892, $1.75; BONNEY, *Ice Work, Past and Present*, Appleton & Co., N.Y., 1896, $1.50; GEIKIE, *The Great Ice Age*, Appleton & Co., N.Y., 3d ed., 1894, $7.50; TYNDALL, *Glaciers of the Alps*, Longmans, Green & Co., N.Y., 1896, $2.50; SHALER and DAVIS, *Glaciers*, Houghton, Mifflin & Co., Boston, 1881, $10; LUBBOCK, *The Scenery of Switzerland*, Macmillan Co., N.Y., 1898, $1.50; SALISBURY, *Glacial Geology*, Vol. V, 1902, New Jersey Geological Survey, Trenton, N.J.; NANSEN, *First Crossing of Greenland*, Longmans, Green & Co., N.Y., 1892, $1.25; PEARY, *Northward over the Great Ice*, P. A. Stokes, N.Y., 1898, $6.50; DRYER, *Studies in Indiana Geography*, Inland Publishing Co., Terre Haute, Ind., 1897, $1.25. U. S. Geological Survey as follows: RUSSELL, *Existing Glaciers of United States*, 5th Annual, p. 309; *Malaspina Glacier*, 13th Annual, p. 7; REID, *Muir Glacier*, 16th Annual, p. 421; CHAMBERLIN, *Terminal Moraine*, 3d Annual, p. 295; *Striæ*, 7th Annual, p. 155; LEVERETT, *Illinois Glacial Lobe*, Monograph XXXVIII; *Glacial Formations, etc., of the Erie and Ohio Basins*, Monograph XLI; STONE, *Glacial Gravels of Maine*, Monograph XXXIV; UPHAM, *Glacial Lake Agassiz*, Monograph XXV.

CHAPTER IX.

LAKES AND SWAMPS.

LAKES.

116. Origin of Lake Basins. — A lake is a body of water occupying a basin or depression on the surface of the land. Lakes form parts of river systems, but their basins are not usually made by the rivers. In their work of valley cutting, rivers tend to establish regular slopes, and they are capable of making only small basins: for example, pot holes (p. 54) and ox-bow lakes (p. 63). Rivers could not make deep basins because water would gather in them and check the current, thus taking away its cutting power. The majority of lake basins are formed by dams across stream valleys.

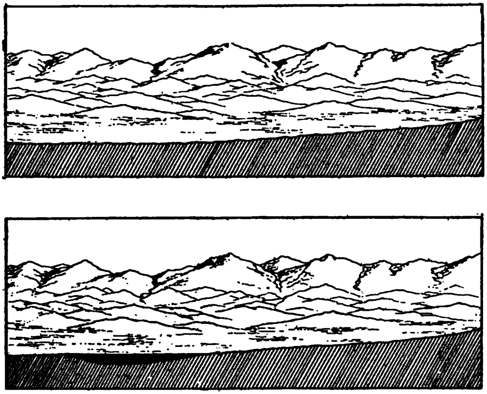


FIG. 296. — Two diagrams of the same valley. In the lower figure a lake has been formed by downfolding, or warping, of its bottom.

Most of the leading causes for lake basins have already been stated. (See pages 55, 60, 63, 67, 76, 78, 95, 97, 103, 121, 123, 130, 131, 142, 148, 149, 154, and 156.) Make a list of these causes. From it you will see that there are various reasons why

FIG. 297. — A view on Lake Como, occupying a mountain valley broadened and deepened by glacial erosion and dammed by deposit of moraine across the valley. A hanging valley (p. 142) is seen on the opposite side. The town in the foreground (Bellano) is on a stream delta, which has been built out into the lake.

FIG. 298. — Lake Cayuga, central New York, occupying a river valley broadened and deepened by glacial erosion and dammed at one end by drift deposits.

FIG. 299. — Lower Ausable lake in the Adirondacks, occupying a mountain valley dammed by drift.

dams may be made across stream valleys, changing them to lake basins. By far the most important of these causes are the glacial dams which have so recently interfered with the drainage of large areas of Europe and America. Many lakes, such as the Great Lakes (p. 156), are due to a combination of two or more causes.

There are still other causes than those already stated for lakes and ponds. For example, beavers build dams of wood and mud across streams to make swamps and ponds for their homes and feeding grounds. Man is now one of the most important agents in the making of lake basins. To supply water for power, for the use of cities, and for irrigation, men are making ponds and lakes in many parts of the earth.

Summary. — *Lake basins, though parts of river systems, are not generally formed by the rivers, but by some interference with drainage, usually by some kind of a dam. Man is now making many lakes.*

117. Size and Form of Lakes. — There is every gradation from mere ponds to the largest of lakes. Some are very shallow; others have great depth; in many the bottom is below sea level; and even the surface of some, like Dead Sea, is below sea level. The following tables give some facts regarding the size and depth of certain large lakes.

THE GREAT LAKES.

	Length, miles.	Average width, miles.	Maximum width, miles.	Shore line, miles.	Water area (including is'ds.), square miles.	Average depth, feet.	Maximum depth sounded, feet.	Surface above tide water, feet.	Deepest point above tide water, feet.	Water volume, cubic miles.	Land area of water-shed, square miles.	Aggregate land and water area of water-shed, square miles.
Superior . . .	390	70	160	1,300	31,200	475	1,008	602	–406	2,800	51,600	82,800
Michigan . . .	335	58	85	875	20,200	335	870	581	–289	1,290	37,700	60,100
Huron	250	54	100	725	17,400	210	702	581	–121	650	31,700	55,700
Erie	25	40	58	590	10,000	70	204	573	369	130	22,700	32,700
Ontario	180	40	58	600	7,300	300	738	247	–491	410	21,600	28,900

SOME OF THE LARGEST LAKES IN THE WORLD.

NAME.	AREA (SQUARE MILES).	ELEVATION (FEET).	GREATEST DEPTH (FEET).
Caspian	169,000	-85	2,400
Superior	31,200	602	1,008
Victoria Nyanza	30,000	4,000	590+
Aral	26,900	160	225
Huron	17,400	581	702
Michigan	20,200	581	870
Nyassa	14,000	1,500	600+
Tanganyika	12,650	2,800	2,100
Baikal	12,500	1,312	4,550
Great Bear	11,200	200	——
Great Slave	10,100	——	650+
Chad	10,000+ variable	8-900	12
Erie	10,000	573	204
Winnipeg	9,400	710	70
Balkash	7,800	780	135+
Ontario	7,300	247	738

The great majority of lakes are longer in one direction than in others. The explanation of this fact is that they occupy parts of river valleys, and, therefore, have a long axis in the direction of the valley. If the water rises into tributary valleys, the outline of the lake becomes irregular, as in the case of Lake Champlain. Because the basin which they occupy is round, some lakes are nearly circular. This is true, for instance, of crater lakes (Figs. 215, 216, 225), sink-hole lakes (p. 60), and kettle-hole ponds (Fig. 294).

Deltas built out into lakes help to make them irregular; and, on the projecting deltas, towns and villages are often placed (Figs. 107, 297). Deltas at the head of lakes, where the inlet streams enter, shorten the lake.

On the other hand, waves tend to straighten lake shores by cutting back headlands and building beaches, which often shut in small bays, transforming them to ponds (Fig. 370).

FIG. 300. — Lake Lucerne, a very irregular lake occupying some of the mountain valleys of the Alps.

Fig. 301. — A map showing the extent of ancient Lake Bonneville, as indicated by the beaches and other shore lines on the surrounding mountain slopes. The present Great Salt Lake is shown occupying a part of the desert plain on the site of this extinct lake.

Summary. — *Lakes vary greatly in size, depth, and form; but most lakes are long, because they occupy parts of river valleys. Deltas on the sides of lakes make them irregular; but waves tend to straighten the shores.*

118. Salt Lakes. — The largest lake in the world, the Caspian Sea, is salt. It receives an enormous inflow of fresh water from the Volga and other rivers; but in that dry climate, evaporation is so rapid that the water does not fill the basin and overflow. Its surface is about 85 feet below sea level.

Dead Sea, whose surface is 1300 feet below sea level, is one of the saltest lakes in the world, being nearly a quarter salt, although entered by the fresh-water Jordan.

Great Salt Lake is about one fifth salt; and this amount so increases the density of the water that a man cannot sink in it. Where the water has risen over the low plain surrounding the lake, and evaporated, the ground is incrusted with salt; and, by leading the water into shallow basins, and allowing it to evaporate, salt for use is obtained.

The explanation of salt lakes in dry climates is as follows. Streams carry salt, gypsum, carbonate of lime, and other mineral substances in solution (p. 51). Where lakes have outflows, these substances are borne away by the outlet streams; but in arid climates evaporation is so great that the lakes cannot rise and overflow the rims of their basins. Therefore, while the water is removed by evaporation, the mineral substances are left, and the water grows gradually salter. If evaporation continues long enough, there will be so much salt that some of it must be deposited on the bottom. Great Salt Lake is not yet salt enough for this; but carbonate of lime is being deposited.

In the Great Salt Lake basin there are wonderfully perfect deltas, beaches, and wave-cut cliffs on the mountain sides, hundreds of feet above the valley bottom. By tracing these shore

lines it is found that a great fresh-water lake, now named Lake Bonneville (Fig. 301), formerly filled this basin, overflowing into the Columbia. Its area was as great as that of Lake Huron, and, on the site of Salt Lake City (Fig. 133), the water was over 1000 feet deep. Great Salt Lake is the shrunken descendant of Lake Bonneville, occupying a shallow depression on the lake-bottom plain. In other arid regions there is evidence of former periods of greater moisture.

Summary. — *Salt lakes, common in arid regions, are due to the fact that evaporation prevents the water from rising to a point of overflow, and, by removing the water, leaves behind salt and other dissolved mineral substances. Elevated shore lines around the basin of Great Salt Lake prove former periods of greater moisture.*

119. Life History of Lakes. — Some lakes disappear by the sudden removal of the dam, as in the case of glacial lakes (p. 149); others, like Lake Bonneville, disappear by evaporation. But most lakes have a different life history, being destroyed partly by filling, partly by cutting down at the outlet. Cutting at the outlet is usually slight, because the sediment has been filtered out in the quiet lake water, thus robbing the outlet stream of tools for erosion. This is illustrated by Niagara River, which, though emerging from Lake Erie with great volume, has been able to do little more than cut a shallow valley in the loose glacial drift (Fig. 483).

Every stream that enters a lake is bringing to it sediment which is helping to fill the basin; and the waves, winds, and rain wash add to this sediment supply. The finer rock fragments are carried out into the lake and strewn over its bottom, while the coarsest fragments are deposited near the shore, especially opposite the stream mouths, building deltas. (Figs. 107, 293, 297.)

As soon as part of a lake becomes shallow enough, vegetation commences to grow in the quiet water (Figs. 303, 306). The death of these plants — including lilies, reeds,

cane, and sphagnum moss — supplies further material for lake filling. Gradually the lake is replaced by a swampy plain (Fig. 304), the upper layers of which are made of vegetable remains.

Over this swampy plain the streams meander, gradually building it higher by flood deposits until it becomes a dry-land plain. During its existence, a lake acts as a temporary base level, below which the incoming streams cannot cut. But when a lake is filled, the outlet stream, being no longer robbed of its sediment, is able to cut more rapidly; and, as the outlet stream deepens its valley, opportunity is given for the streams on the lake plain to cut valleys. Then the sediment with which the lake basin has been filled is slowly removed. In the glacial belt there are many illustrations of partly or completely filled lakes and ponds; and among mountains every gradation in lake destruction is found, even to the point where all lake sediment has been removed.

Summary. — *Lakes are normally removed by combined cutting at the outlet and filling with sediment; but down-cutting at the outlet is usually slight because the outflowing streams have little sediment. Plant growth, and the floods of streams that flow over the swampy plain, accomplish the final stage. When filling is complete, the streams are able to cut into these lake beds and remove them.*

120. Importance of Lakes. — Lakes are highly important as resorts for people in search of rest and recreation. The beautiful scenery, cool climate, boating, bathing, and fishing attract thousands of people each summer to the Great Lakes, Lake George, Lake Champlain, and the lakes of the Adirondacks, the Catskills, and New England.

Lakes have a decided influence on climate. In summer the water warms less rapidly than the land, and this cools the air over the lakes. In winter, on the other hand, when the land is frozen and snow covered, deep lakes are open and the temperature is, therefore, above freezing point. This open water acts like a great stove, raising the temperature of the air, which winds carry to the neighboring land.

The lake water warms so slowly in spring that its presence chills the land near by and retards the buds of plants. It also helps to prevent late spring frosts. This is very important to delicate plants, like some of the fruits, which are greatly injured by frosts late in spring after the buds have appeared. The water, warmed in summer, also tends to prevent early autumn frosts, and thus the growing season for delicate plants is prolonged. For these reasons lake shores are often the seat of important fruit-raising industries. This is well illustrated on the shores of the Great Lakes. One of the best vineyard regions of the United States is along the south shore of Lake Erie; and the peninsula of Ontario, between Lakes Erie, Ontario, and Huron, has so moderate a climate that peaches and tobacco are grown. A similar influence is felt all along the Great Lakes.

Lakes are an important source of food fish. They are also a source of ice, which may be stored for use in summer. To freeze shallow lakes does not require great cold; but large, deep lakes rarely freeze. The reason for this fact is that, until a temperature of 39° is reached, fresh water becomes steadily heavier and sinks. It is, therefore, necessary to lower the temperature of the entire lake to 39° before the surface freezes. The settling of cold water in winter gives to the bottom of lakes a temperature of 39° throughout the year.

Lakes are also of great value in navigation. In early days the Great Lakes were of the highest service as pathways for the explorers of the wilderness; to-day they are thronged with ships going in all directions. By this lake navigation and commerce the location of several great cities has been determined — Duluth, Milwaukee, Chicago, Detroit, Toledo, Cleveland, Buffalo, Toronto, and others (p. 313).

The building of railways into the interior of Africa is now opening up the great African lakes to navigation. They have already been important factors in the development of tropical Africa, and were traversed by steamboats even at the time when it was necessary for all the machinery to be carried to them on the backs of men.

FIG. 302. — The town of Interlaken on the delta which has divided an Alpine lake into two lakes, Thun and Brienz. The stream connecting the two is seen in the picture.

Fig. 303. — A pond in which vegetation is aiding in filling. Lilies are the farthest out, then low shrubs, then low trees, and finally the forest.

Fig. 304. — A filled pond in the Adirondacks, showing the swamp plain and the stream crossing it. It is still too swampy for trees to grow. (Copyright, S. R. Stoddard, 1888.)

As storage basins and regulators of water supply, lakes serve still another important purpose. While the volume of such rivers as the Mississippi varies with the rainfall, the lake-fed Niagara and St. Lawrence maintain a very uniform flow. It is because they store large quantities of water for steady supply that lakes and ponds are so useful for city water supply, for factories, and for irrigation. The fact that sediment settles in lakes makes them of further value in supplying clear drinking water, even though entered by very muddy streams. Indeed, ponds are often made part of a city water supply for this very purpose of removing sediment.

The drying up of salt lakes leaves beds of salt, some of which are found on the surface of arid lands, as in western United States; others are buried deep in the earth. Dried-up salt lakes also supply other mineral substances, one of the most important being gypsum, which is used for plaster of paris, land fertilizer, and the "chalk" of crayons.

Summary. — *Lakes are important as resorts; they have decided influence on the climate of near-by land; they are a source of ice; they supply food fish; they are very useful for navigation; they act as storage reservoirs for a steady supply of water, and as settling basins for sediment; and dried-up salt lakes furnish beds of salt, gypsum, and other mineral substances.*

SWAMPS.

121. Causes of Swamps. — A swamp is a damp place on the land, not ordinarily covered by standing water. It is caused by some interference with the run-off of water, such as a gentle slope, or the growth of swamp-loving vegetation. One of the most common causes for swamps is the filling of lakes, forming such a level surface that swamp plants grow in abundance. During the stages of lake filling, swamps are formed on deltas, in bays, and, if the lake is small, even along the shores (Figs. 303, 306); and, when completely filled, the lake is replaced by a swamp (Fig. 304).

In cool, damp, temperate climates, the most important swamp-producing plant is the sphagnum moss, which forms *peat bogs.* Sphagnum often grows out from the shores of small, shallow ponds, floating on the surface (Fig. 305), and, by the decay of its lower parts, causing a deposit of vegetable muck on the bottom. Eventually the sphagnum may reach entirely across a pond, with growing plants above and a thick, liquid mass of decaying vegetation below. It is then called a *quaking bog* (Fig. 305), because it trembles, or quakes, under the foot. If one sinks into the muck below, escape is impossible. Very perfect remains of extinct animals, and even of men, have been found in the peat bogs of Ireland, the decaying vegetation forming preserving acids which interfere with decay.

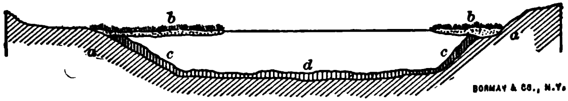


Fig. 305. — To show the growth of sphagnum moss out from the shore, forming a quaking bog. In time the moss from the sides will meet, completely inclosing the pond, and, by its decay, covering the entire bottom with muck.

Swampy or boggy places are common on hillsides where springs appear, encouraging the growth of sphagnum and other swamp plants. Sphagnum holds water like a sponge, and is thus able to grow some distance from the spring; in fact, it may even climb the hillside, making a *climbing bog.* In the damp climate of Ireland, climbing bogs sometimes become so heavy with water that they slide down the hillside, becoming "bursting bogs," by which both life and property have been destroyed.

The Arctic tundra, in winter a frozen, snow-covered desert, in summer becomes a vast swamp, wherever there is soil. The reason for this is that the melting frost makes the ground wet, as it does in all cold climates in spring. Every rain makes the tundra more swampy, partly because the frost prevents the water from soaking into the ground, and partly because it helps the frost to melt. In this swampy land mosquitoes develop in such numbers as to become a great pest.

The overflow of rivers causes swamps in low places on floodplains, especially on the low ground just behind the natural levees. These swamps are unfit for cultivation and are, therefore, occupied by dense forests of cypress, black gum, and other swamp-loving trees (Fig. 308). Swamps are also found along the lower courses of rivers, where the river water is backed up by the tide and caused to overflow low land (Fig. 121).

Level coastal plains (p. 72) often have such a gentle slope that the water cannot run off; and the drainage is further interfered with by the rank growth of vegetation which the water encourages. Such swamps are found on the coastal plain of Texas and in Florida (Figs. 78, 79), especially in the Everglades region. The famous Dismal Swamp on the coastal plain of Virginia and North Carolina is another illustration (Fig. 307). By clearing off the vegetation, and cutting ditches for the water to run through, parts of Dismal Swamp have been drained.

Naturally there are few swamps in arid lands; but some are found near springs and on the river floodplains. There are also marshy places — *alkali flats* and *salines* (p. 87) — in which only a few species of plants can grow. At times of flood they may become shallow, muddy lakes, called *playas;* but, at other seasons, evaporation changes them to hardened mud, crusted over with alkali and salt. When wet, the deep, sticky mud often makes them quite impassable.

Swamps, or marshes, are also found on the seacoast (pp. 216, 217).

Summary. — *Swamps are caused during the filling of lakes, one form of such swamps being the peat bog, formed by the growth of sphagnum moss. Sphagnum also makes swampy places around springs, and climbing bogs on hillsides. The melting of frost in summer causes the Arctic tundra to be swampy wherever there is soil. Swamps also occur along rivers and on level coastal plains. In arid lands, where evaporation causes a deposit of salt or alkali, there are swampy tracts, called alkali flats and salines.*

122. Effects of Swamps. — The dampness of swamps makes them unhealthful; and malaria, transmitted by mosquitoes which breed in the water, prevails in many swamp regions. In tropical regions, as along the narrow coastal plain of the central African coast, and in central America, fever is so common that white men suffer even in crossing the level, damp lowland. Because of malaria, parts of Italy have become quite deserted; and some of the river bottoms and rice swamps of the South have been left to the negroes, who suffer little from the unhealthful climate.

Swampy conditions unfit land for most purposes except rice production; but, when drained, the rich, black soil is very productive. For this reason, as well as for the sake of health, swamp lands are being drained, where possible. This has been done much more extensively in Europe than in America, where land is less valuable. The most extensive drainage has been carried on in the Netherlands, where the low, swampy delta of the Rhine, and even part of the shallow sea bottom, have been protected by dikes, and drained by pumping. About one half of the Netherlands is reclaimed land, a large part of it being below sea level.

The salines of arid lands have valuable stores of salt; and the peat bogs of cool temperate climates are important sources of fuel. Coal and wood are so abundant in America that this source of fuel is scarcely touched; but in northern Europe it is a very important fuel, being cut out with spades (Fig. 309) and dried and stored for winter. Coal beds are similar swamp deposits, made ages ago, and covered and preserved beneath thick beds of sediment. The swamp deposits of Florida would, if covered with layers of sediment, slowly change to coal.

Summary. — *Swamps are unhealthful, being a source of malaria; they are of little value unless drained; but the salines supply salt, and the peat bogs fuel. Coal is made of swamp deposits, slowly changed to mineral and preserved beneath beds of sediment.*

Fig. 306. — A lake in the Adirondacks (Fifth Lake, Fulton Chain) in which vegetation is aiding in filling. By this the lake shores have been changed to swamps.

Fig. 307. — A view in the Dismal Swamp. The cypress knees and roots are seen rising to a level above the reach of high water.

FIG. 308. — A river swamp in Mississippi.

FIG. 309. — Digging peat in a bog in Ireland.

Topical Outline, Questions, and Suggestions.

Topical Outline. — 116. **Origin of Lake Basins.** — Definition; impossibility of formation of large basins by rivers; causes for lakes; most important cause; combination of causes; effect of beavers; of man.

117. **Size and Form of Lakes.** — Variation in size; in depth; long lakes; irregular lakes; circular lakes; effect of deltas; effect of waves.

118. **Salt Lakes.** — (*a*) Instances: Caspian Sea; Dead Sea; Great Salt Lake. (*b*) Cause: source of salt; failure to overflow; increasing saltness. (*c*) Former moist periods: shore lines; Lake Bonneville.

119. **Life History of Lakes.** — Exceptional causes for removal; cutting at outlet; slight importance; sources of sediment; places of deposit; effect of vegetation; change to dry land; removal of lake beds.

120. **Importance of Lakes.** — (*a*) Summer resorts: reason; instances. (*b*) Climate: summer influence; winter; spring; autumn; effect on vegetation; illustrations. (*c*) Food fish. (*d*) Freezing: ice; reason why deep lakes do not freeze. (*e*) Navigation: Great Lakes; cities; African lakes. (*f*) Water supply: effect on floods; storage of water; settling of sediment. (*g*) Dried-up salt lakes: salt; gypsum.

121. **Causes of Swamps.** — (*a*) Definition. (*b*) Lake swamps; filled lakes; lake shore swamps. (*c*) Peat bogs: sphagnum; quaking bogs; animal remains. (*d*) Hillside swamps: springs; climbing bogs; bursting bogs. (*e*) Tundra swamps: in winter; in summer. (*f*) River swamps: floodplains; in lower course. (*g*) Coastal plain swamps: cause; illustrations; drainage. (*h*) Arid land swamps: scarcity; alkali flats; salines; playa lakes. (*i*) Seashore swamps.

122. **Effects of Swamps.** — Effect on health; effect on cultivation; drained swamps; Netherlands; supply of salt; of peat; origin of coal.

Questions. — 116. Why is it not possible for rivers to excavate large basins? State the causes for lake basins.

117. How do lakes vary in size and depth? In form? Why? What effects have deltas? Waves?

118. What is the condition of Caspian Sea? Dead Sea? Great Salt Lake? What causes salt lakes? Describe Lake Bonneville.

119. What happens at the outlet of most lakes? With what materials are lakes filled? What is the last stage in the life history of lakes?

120. Why are lakes favorite summer resorts? How does the lake water influence climate? What effect has this on vegetation? Why do not deep lakes freeze? Give illustrations of the value of lakes in navigation. What effect have lakes on water supply? What important mineral substances are supplied from dried-up salt lakes?

121. What is a swamp? In what ways are swamps associated with lakes? What are peat bogs? Quaking bogs? Climbing bogs? Why are tundras swampy in summer? Where near rivers do swamps occur? Why are swamps common on coastal plains? Give illustrations. What are alkali flats and salines? Playas?

122. What effect have swamps on health? What effect have swamps on agriculture? How may they be made valuable? What fuel is supplied from swamps? What is the origin of coal?

SUGGESTIONS. — (1) Make a valley in clay and pour water into it. It is a stream valley. Place a dam across it and make a miniature lake. What is its shape? Make one or two tributary valleys into which the water rises. What is the shape then? Wash sediment into the lake by sprinkling the sides with a watering pot. Notice the growth of deltas. The lake may even be filled. (2) In a deep jar of water, take the temperature at the top and bottom. Pound up ice and put it into the jar, and when it has all melted, again take the temperature at the top and the bottom. Why has the bottom water this temperature? Continue putting in ice until the temperature at the surface is 36°. What is the temperature at the bottom then? (3) Place a large dish of warm water in a cold room. Does the temperature of the air change as a thermometer is brought near the water? Try the same experiment with a large dish of ice-cold water in a warm room. (4) If your home is near a lake, study it. Can you find out what caused it? Does the outlet stream flow in a deep or shallow valley? Are there any deltas? Where? Any signs of filling by wave action? Are there any swamps? What kinds of plants grow on the shallow lake bottom and shore? (5) Are there any swamps near your home? What is their cause? Is it believed that they are unhealthful? Are any of them partly or wholly drained? How was it done? What effect has the draining had? (6) Make three surfaces of clay: (1) a steep slope, (2) a plain, (3) a plain with vegetation (made by putting pieces of grass in it). Sprinkle with water. Which remains wet longest? Why? Which dries first?

Reference Books. — RUSSELL, *Lakes of North America*, Ginn & Co., Boston, 1895, $1.50; TARR, *Physical Geography of New York State*, Chapter VI, Macmillan Co., N.Y., 1902, $3.50; GILBERT, *Lake Bonneville*, Monograph I, U. S. Geological Survey; *Lake Bonneville*, 2d Annual, U. S. Geological Survey, p. 169; RUSSELL, *Present and Extinct Lakes of Nevada, National Geographical Monographs*, American Book Co., New York, 1895, $2.50; *Lake Lahonton*, 3d Annual, U. S. Geological Survey, p. 195; *Lake Lahonton*, Monograph XI, U. S. Geological Survey; *Mono Lake Region*, 8th Annual, U. S. Geological Survey, p. 267.

CHAPTER X.

THE OCEAN.

123. Importance of the Ocean. — We have already learned (p. 15) that the ocean is in many ways of importance to man. It supplies vapor for rain, and moderates the climate of the lands; it is a source of food and other products that man needs; and it is an important highway of communication between all quarters of the globe.

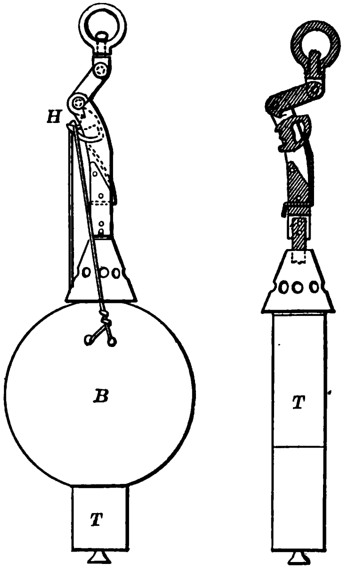


FIG. 310. — Deep-sea sounding apparatus. *B*, cannon ball suspended from hook *H*, which drops when the apparatus strikes the bottom, releasing the ball, as shown in the right-hand figure.

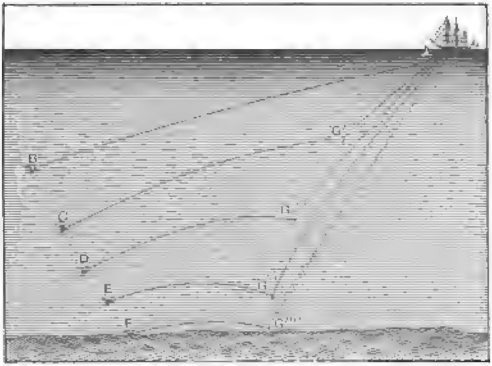
THE OCEAN BOTTOM.

124. Oceanography. — Oceanography is the study of the ocean, both the surface and the bottom. For carrying on this study there have been numerous exploring expeditions, the most important being that of the British ship *Challenger*, which spent four years in studying the Atlantic, Pacific, Indian, and Southern oceans. Other governments have also sent out ships for this purpose, among them the U. S. Coast Survey steamer *Blake* and the U. S. Fish Commission steamer *Albatross*. One reason for a special study of

the ocean is to determine its depth and the nature of its bottom in order to discover proper lines for submarine cables. These cables are so important in commerce and war that lines now cross the oceans in various directions.

To determine the depth, use is made of a sounding machine which lowers an iron weight, usually a cannon ball, to the bottom. This heavy weight is not drawn back to the surface, but is automatically released when bottom is struck (Fig. 310).

A sample of the ocean-bottom water is brought up in a metal tube, or water bottle (*T*, Fig. 310), which remains open on the way down, but closes when drawn up. A sample of the ocean-bottom mud clings to soap or tallow placed on the bottom of the water bottle; and the temperature is determined by thermometers attached at various points on the sounding line. These deep-sea thermometers are so made that they record the temperature at the point where they begin to be drawn up. Thus, by a single sounding, the depth, some of the water, a sample of the bottom, and the temperature of the water at various points are all obtained.



BORMAY & CO., N.Y.

FIG. 311.—Apparatus used by the *Challenger* in dredging. *G* is a weight, and *B*, *C*, *D*, *E*, and *F* represent various positions of the dredge.

Most deep-sea exploring expeditions also make a study of the animal life of the ocean bottom. Specimens of these animals are obtained by means of a deep-sea dredge, or trawl (Fig. 312), which consists of an iron frame several feet in length with a long bag net attached. This is dragged over the ocean bottom (Fig. 311), animals in its path being scooped up by the frame and gathered in the bag. Many weird creatures are thus obtained.

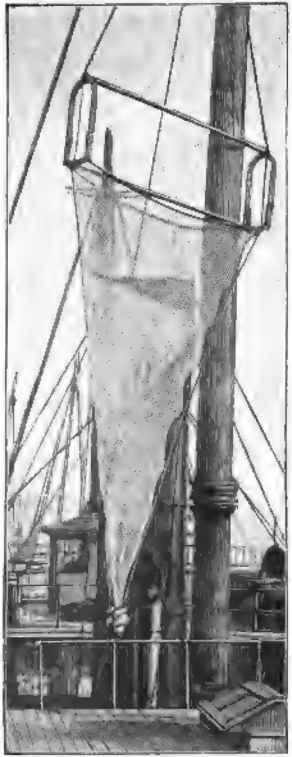


FIG. 312. — Deep-sea trawl used by the U. S. Coast Survey.

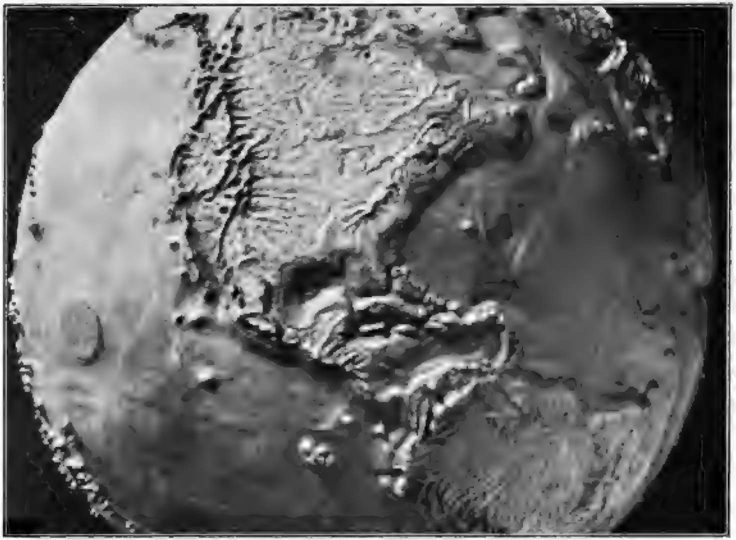


FIG. 313. — The continent of North America and neighboring sea bottoms, showing the continent block; the continental shelf plains; the continental slopes; and the great ocean-bottom plains. In the Pacific are some volcanic cones; and the West Indies are seen to be mountains rising from the sea bottom.

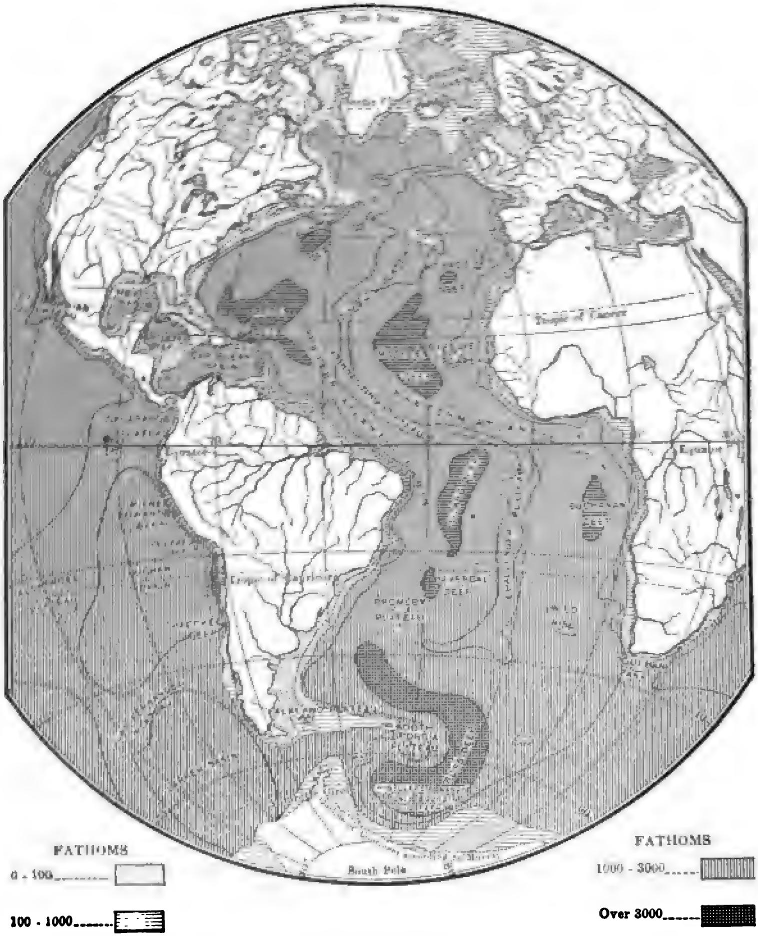


Fig. 314. — The depths of the Atlantic in fathoms (a fathom is six feet). The mid-Atlantic ridge is called Dolphin, Connecting, and Challenger plateaus. Note the continental shelves, dotted.

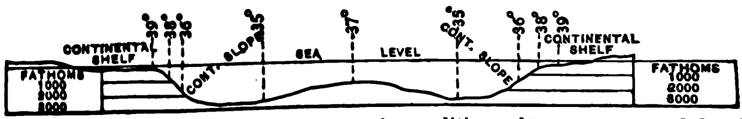


Fig. 315. — Section to show, in diagram, the conditions of temperature and depth in the Atlantic. Ocean depth and width of continental shelf greatly exaggerated. The raised portion in the center represents the mid-Atlantic ridge.

Summary. — *For a study of the ocean, or oceanography, there have been numerous government exploring expeditions, one of whose objects has been to determine the best lines for cables. In the study of the ocean bottom the depth, nature of the water, nature of the bottom, temperature, and kind of animal life are usually determined.*

125. Ocean Basins. — Exploration has shown that the ocean bottoms are mainly vast submarine plains (Figs. 313, 316). Beyond the continental slopes (p. 22) almost the entire ocean floor is a monotonous plain, occupying about two thirds of the earth's surface (Fig. 19). Here and there a portion is sunk below the rest, forming a *deep* (Fig. 314); and here and there volcanic peaks or mountain ridges rise from the ocean floor (Fig. 313), sometimes reaching above the surface. But these elevations and depressions are only exceptions to the general levelness.

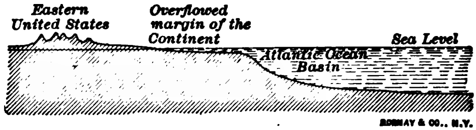


FIG. 316. — Rising of the ocean water over the continental slope overflowing the continent margin or shelf (p. 72).

The Blake deep, not far from Porto Rico, is the deepest known point in the Atlantic Ocean, 27,360 feet (Fig. 313). There are a number of volcanic peaks in the Atlantic, such as the Bermudas, the Azores, the Canaries, Cape Verde Islands, and St. Helena. In the mid-Atlantic there is a low, irregular elevation, or a series of submarine plateaus (Fig. 314), sometimes called the *mid-Atlantic ridge* (Fig. 315). There are deeps on either side of it. This upraised portion extends the whole length of the Atlantic, usually several thousand feet beneath the surface.

There are hundreds of volcanic peaks in the open Indian and Pacific oceans (Fig. 313), usually in chains along the crests of submarine mountain uplifts, — for example, the Hawaiian chain, and the Ladrone chain, of which Guam is one peak. The deepest known point in any ocean, 31,600 feet, is the Challenger deep, near Guam. The Aldrich deep, near New Zealand, is 30,930 feet; and the Tuscarora deep, east of Japan, 27,930 feet.

Little is known about the Arctic and Southern oceans; but Nansen found a depth of over 12,000 feet in the Arctic, and parts of the Southern Ocean are also known to be very deep.

Summary. — *Beyond the continental slope is a vast expanse of plain, covering about two thirds of the earth's surface. There are occasional deeps sunk below its general level, and volcanic cones and mountain ridges rising above it.*

126. Deposits on the Ocean Bottom. — (A) *Rock Fragments.* — The wind, rain, rivers, and waves drag fragments from the land into the sea. Most of this sediment settles in the quiet water near the coast; but currents drift some of the finer particles out to sea, even to the edge of the continental shelf.

This sediment fills depressions and tends to smooth over the irregularities of the continental shelf; and, by its accumulation, it makes beds of sedimentary rock, coarsest near the coast (p. 32). Remains of ocean animals also accumulate on the bottom and add to the deposit of sediment, being preserved in the rocks as fossils.

Fig. 317. — A magnified sample of globigerina ooze from the ocean bottom.

Summary. — *Near the continents the ocean bottom is covered with layers of rock fragments derived from the land.*

(B) *Ocean-bottom Oozes.* — So little rock waste is dragged far out to sea that the contribution of animal remains exceeds that of rock waste. More than a third of the ocean bottom is covered with an ooze, composed mainly of animal and plant remains. This deposit contains a small

percentage of rock fragments, especially pieces of volcanic ash and pumice that, on becoming water-logged, have settled to the bottom. The ocean-bottom ooze is made partly of organisms that live on the bottom, but mainly of the shells of microscopic organisms that live in vast numbers in the surface waters and, on dying, settle to the bottom.

The ocean-bottom ooze is given different names according to the organisms that are most abundant. Thus a large part of the ocean-bottom deposit is called *globigerina ooze* (Fig. 317), because of the abundance of microscopic Globigerina (Fig. 318). Chalk is a similar ooze deposited on the bottom of ancient seas. There is also *pteropod* and *diatom ooze.* The latter is made of siliceous parts of microscopic diatom plants which thrive especially in the cold waters of the Southern Ocean.

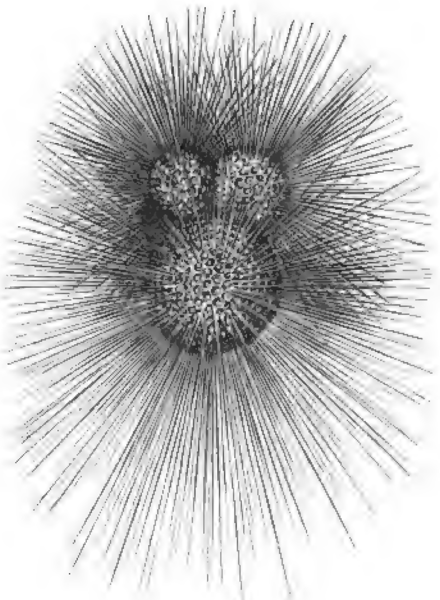


Fig. 318. — A specimen of Globigerina from the surface, greatly magnified.

Summary. — *Far from land, where there is little rock waste, the ocean bottom is covered with globigerina and other oozes, made largely of the remains of organisms, mostly microscopic surface forms.*

(C) *Red Clay.* — The shells that sink to make globigerina ooze are composed of carbonate of lime, but contain a very small percentage of other substances, such as iron and silica. In the very deep ocean water (12,000 to 15,000 feet or more),

which contains much carbon dioxide, these limy shells are dissolved; but the iron, silica, etc., are not so readily soluble, and they pass on to the bottom forming a clay, colored red by iron oxide. More than a third of the ocean bottom is covered with this red clay, whose rate of deposit must be very slow since it is formed of the very small insoluble portion of shells that are themselves microscopic.

Other facts further prove that the red clay is formed with wonderful slowness. Scattered through it are fragments of pumice, bits of meteoric iron, the teeth of sharks, and the ear bones of whales. There are not many whales or sharks in one place, nor are many meteorites falling. If the red clay were not accumulating very slowly, these objects would be so deeply covered that a small dredge would rarely find any; yet deep-sea dredging often brings them to the surface.

Summary. — *Red clay covers the deeper parts of the ocean bottom; that is, over one third of the entire ocean floor. It is a very slowly forming deposit, made of the insoluble remnants of microscopic shells that have been dissolved in the deep-sea water.*

127. Land and Ocean-bottom Topography. — There are three important reasons why the ocean bottom is far more regular than the land surface (p. 21). (1) While mountain folding and volcanic action cause irregularities both on land and ocean bottom, they are less important in the sea than on the land. (2) Erosion sculptures the land into hills and valleys; but the ocean water protects the bottom from these agents. (3) Sediment washed from the lands, and the settling of organisms to the bottom, tend to smooth the sea floor.

Because of these facts, if a smooth sea-bottom plain is raised into the air, it is soon carved by erosion into a series of hills and valleys; but if an irregular, hilly land is sunk beneath the sea, it is soon smoothed over by a blanket of sediment (p. 72). There is a striking difference between the widespread smoothness of ocean-bottom plains and the pleasing irregularity of the lands.

Summary. — *The ocean bottom is far smoother than the lands because of* (1) *less mountain folding and volcanic action;* (2) *absence of erosion; and* (3) *widespread deposit of sediment.*

THE OCEAN WATER.

128. Surface of the Sea. — Elevations on the land are measured from *sea level*, by which is meant the approach to a spherical form which the water assumes under the pull of gravity (p. 8). The level of the sea is not perfectly in accord with the spherical form of the earth; for the curved water surface is distorted a little by the attraction of the continents, slightly raising its level near the coast. Winds and storms (p. 271) cause local disturbances of sea level; but, as soon as the disturbing cause has passed, gravity draws the water back to its former level.

There are two causes which are slowly operating to change the level of the sea. The less important of these is the deposit of sediment, which tends to slowly raise sea level. It would take long periods of time for this to produce a great effect, for there is a vast amount of water to be raised. Even if all of North America above sea level were put into the Atlantic, the surface of the oceans would not be raised many feet. The second cause for change in level is movement of the ocean bottoms. There is good reason for believing that, during past ages, the ocean basins have been slowly growing deeper. The effect of such a movement would be to gradually withdraw the waters from the lands.

Summary. — *Sea level is slightly disturbed by the attraction of the continents; locally, and for short times, by winds and storms; and very slowly by* (1) *the deposit of sediment in the oceans and* (2) *the sinking of the ocean bottom.*

129. Composition of Sea Water. — Every one is familiar with the saltness of the sea. Probably salt and other mineral substances were held in solution when the oceans first gathered; but certainly some is being added every day. The vapor

that rises from the ocean does not remove these mineral substances; but when it falls on the land as rain, it begins to wash more dissolved mineral matter into the sea (p. 51). It would seem, therefore, that the ocean must be growing steadily salter.

About three and a half per cent of ocean water is dissolved mineral matter, more than three quarters of which is common salt. Magnesium chloride and magnesium, calcium, and potassium sulphates are also present; and, in very small quantities, there are many other substances, even including compounds of gold and silver. If all the salt of the oceans could be removed, it would make a layer about 400 feet thick over the lands. In many places where the climate is dry, salt is obtained by evaporating sea water; and many salt beds, like that in central New York, were formed in past ages by the evaporation of the water in arms of the sea, cut off as the Caspian is to-day.

Carbonate of lime, though present in very small quantities, is another important mineral substance in sea water. Many ocean animals, such as corals and shell-fish, use it in the growth of their shells and skeletons. On the death of the animals these have accumulated in beds of limestone which, raised to form land, are now used in building, smelting iron, and making lime.

Some air is mixed with all ocean water, being present even on the ocean bottom, where it is brought by slowly moving currents. A few sea animals, such as the seals and whales, come to the surface to breathe; but the great majority require so little oxygen that they are able to obtain what they need from the air that is mixed with the sea water. Without it most of the ocean animals could not live.

Summary. — *Salt and other mineral substances, including carbonate of lime, of which shells are made, are being constantly washed from the land into the sea. Air mixed with the water supplies the oxygen which makes most of the ocean life possible.*

130. Density and Pressure of Sea Water. — Salt water is heavier, or has a greater density, than fresh water. Calling fresh water 1, the average density of ocean water at the surface is about 1.026. The density is less than the average in the rainy tropical belt, and also near the mouths of great rivers, where a large amount of fresh water is added. It is greater than the average where there is much evaporation, as in the dry trade-wind belt, and in seas inclosed by warm, arid lands, like the Red and Mediterranean seas.

There is an enormous pressure on the bottom of deep oceans. At the depth of a mile every square inch bears a weight of over a ton of water, and the pressure on the bottom of the Aldrich deep is nearly six tons to every square inch. One might expect that such a great weight of water would crush the animals on the ocean bottom; but it produces no more effect on them than does the weight of air (about 15 pounds to the square inch) which our bodies bear.

The reason why this great pressure is not felt is that it affects all parts of the body, both within and without. When deep-sea fishes are brought to the surface, however, and the pressure from outside is reduced, that from within opens cracks in their bodies and often causes their eyes to protrude.

Water, unlike air, is not much compressed, even under the great load that weighs down on the bottom layers. Therefore its density at the bottom does not differ greatly from that at the surface. If it were much compressed, as air is, it might become so dense that objects could not sink through it to the bottom. They would then float around in the dense layers.

Summary. — *Salt water is denser than fresh water; but its density varies somewhat. There is an enormous pressure on the ocean bottom; but, since water is not much compressed under pressure, its density is not greatly increased at the bottom.*

131. Color and Light. — Sunlight illuminates the upper layers of the sea and reaches to the bottom of shallow water. The beautiful blue of the open ocean is partly due to the reflection of

the color of the sky, but chiefly to the same cause which makes the sky blue (p. 233). Sunlight is made of waves of many colors, and in their passage through the water they are separated, or scattered, some of them (the indigo and blue) being reflected back, giving the water its color. Near the shore, where there is more sediment, the green waves are reflected, giving the water its green color. The yellow water near the mouth of the Yellow River of China is colored by the mud that the river brings; the color of the Red Sea is due to minute reddish organisms that float in it.

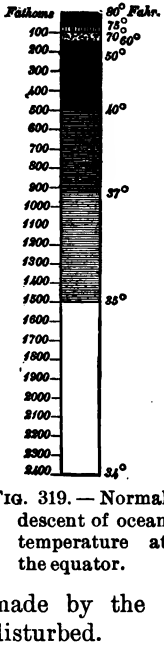


FIG. 319. — Normal descent of ocean temperature at the equator.

No sunlight penetrates to the bottom of the deep sea, which is darker than the darkest night. Having little use for eyes, many of the deep-sea fish are blind; but others have eyes, and many are brilliantly colored. These eyes and colors are doubtless of use because of the phosphorescent glow, like that of the firefly, which many deep-sea animals emit. Indeed, some of the fish have feelers, phosphorescent on the end, which have been called deep-sea lanterns. Phosphorescence is also emitted by many surface animals, and a boat often leaves behind it a trail of faint phosphorescent light, made by the multitude of animalculæ that its passage has disturbed.

Summary. — *The color of the sea is due to the scattering of the waves that compose white light, and the reflection of some of them, such as green, blue, or indigo. No sunlight reaches the ocean bottom, but some of the animals emit a phosphorescent glow.*

132. Temperature of the Oceans. — The surface layers of ocean water are warmed by the sun. Accordingly, while the waters of the frigid zones are nearly at the freezing point of salt water (28° or 29°), tropical waters are warmed to 80° or 85° (Fig. 320). In the inclosed Red Sea, where the

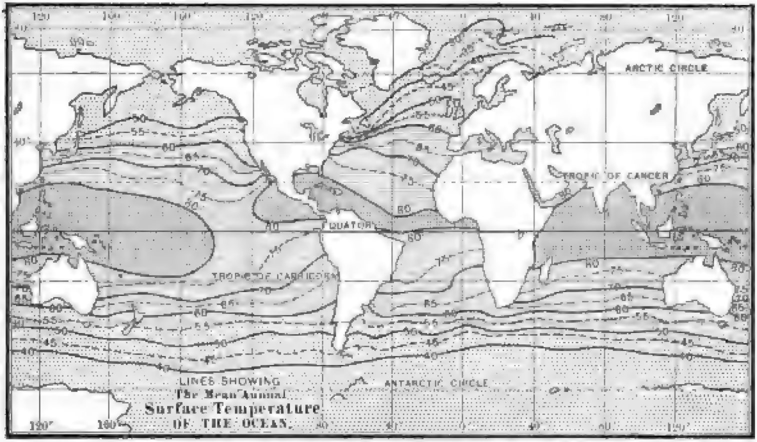


Fig. 320. — **Ocean-surface temperature. The effect of the land, and of ocean currents, makes the temperature lines of the northern ocean far more irregular than those in the southern hemisphere. On an outline map of the world make a sketch map similar to this.**

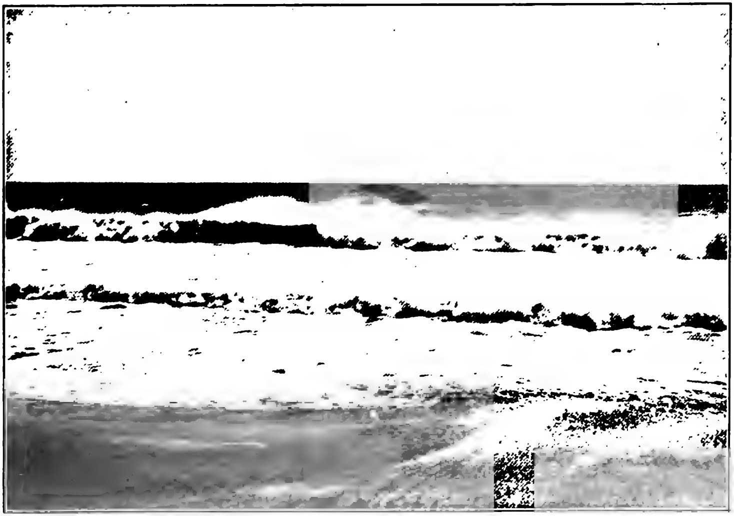


Fig. 321. — **The advance of waves on a beach, forming surf.**

FIG. 322.— A United States government ship (the *Wateree*) stranded on the land in Chile by an earthquake wave in 1869. The surf line is seen one eighth of a mile beyond the farther ship.

FIG. 323.—The bore wave at Moncton, New Brunswick.

entrance of cooler currents is impossible, the temperature may rise to 90° or 95°. Ocean currents greatly influence the temperature of ocean water (p. 194).

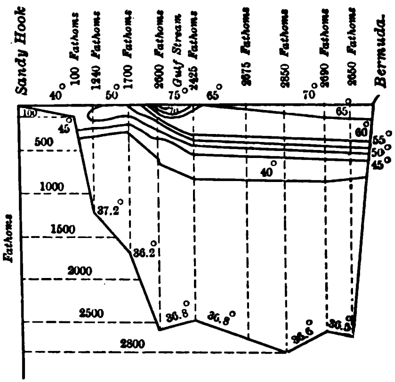


FIG. 324.—Section of the ocean from New York to Bermuda, showing the temperature at various depths.

Since the sun's rays penetrate only the upper layers of the ocean, deep-sea water is not directly influenced by them. If the surface water is warm, the temperature decreases rapidly in the upper layers, then slowly down to the bottom (Figs. 319, 324). Everywhere, even in the torrid zone, the temperature of the ocean bottom is low (Fig. 325); and about four fifths of the ocean water has a temperature of less than 40°.

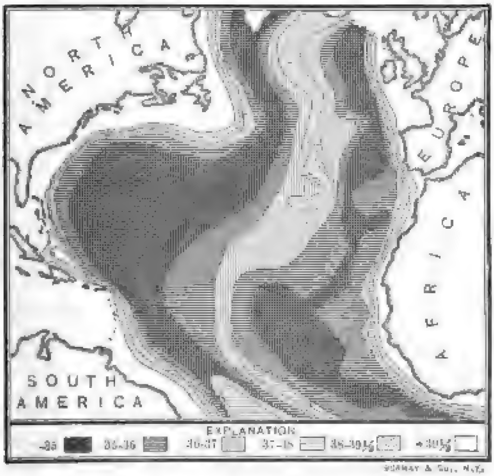


FIG. 325.—Temperature on the bottom of the North Atlantic. The band of higher temperature is on the mid-Atlantic ridge (see Fig. 315).

The explanation of the cold water in the deep sea is that water becomes more dense on cooling, and consequently sinks. While fresh water ceases sinking at 39° (p. 166), salt water continues to

increase in density, and, therefore, to sink, almost until its freezing point is reached. For this reason ocean-bottom water is much colder than that on the bottom of lakes; it may, in fact, be as low as 29°. The settling of cold water in the frigid and cold temperate zones starts a slow circulation along the ocean bottom toward the warm belt, where there is a slow rising. It is this circulation which supplies deep-sea animals with the air they need for breathing.

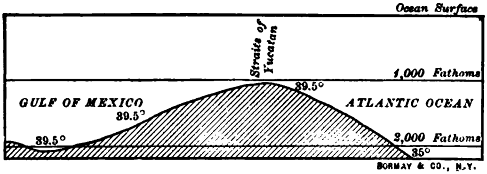


FIG. 326. — The temperature in the Atlantic at a depth of 2000 fathoms is 35°; but in the Gulf of Mexico, at that depth, only 39.5°, which is the temperature at the depth of the barrier (1000 fathoms) over which the water enters the Gulf from the Atlantic.

One of the best proofs of this slow circulation is furnished by such seas as the Gulf of Mexico and the Mediterranean, which are partly shut off from the open ocean. In these seas the decrease in temperature continues down to the level of the barrier, but no lower, because the coldest water that can creep into them is that at the level of the barrier (Fig. 326).

Summary. — *The temperature of the surface water varies with the climate; but settling of cold water, causing a slow circulation, makes the deep sea everywhere cold. Inclosed sea bottoms have the same temperature as that of the open ocean at the level of the barrier.*

MOVEMENTS OF THE OCEAN WATER.

133. Wind Waves. — Blowing on the surface of a dish of water causes small waves. These are similar to the large waves raised on the ocean by the friction of winds that blow over its surface. The water itself does not advance with the wave, but moves up and down, with a slight forward and backward movement. It is the *form* of the wave that advances, as a wave may be made to pass through a rope by shaking it vigorously. Therefore a boat, instead of moving

forward, rises and falls as each wave passes under it; but it is also carried forward and backward a little.

Some of the great ocean waves, raised during heavy gales, have a height of from 30 to 50 feet, measured from the top, or *crest*, to the depression, or *trough*, between two waves. Then the sea presents a wild sight, as the great waves come down upon a ship, their crests broken and whitened by the fierce wind. The wind mixes much air with the ocean water in the foam and spray of these white crests, or *whitecaps* (Fig. 341).

Such waves, moving at the rate of 40 or 50 miles an hour, sometimes dash over the decks, carrying all loose objects along, and even tearing away massive wood and iron work. Even great ocean steamers are, at times, forced to change their course to avoid the danger of being upset by the approach of these huge waves from one side. To smaller boats they are very dangerous, and many a fishing schooner (Fig. 341) has been foundered by them.

The use of oil at sea is now common in violent gales. Dropped on the surface, the oil spreads in all directions; and, as the oily surface offers less resistance to wind, the waves are much less broken. There is then less danger of waves coming aboard.

Waves often appear when no wind is blowing, and even when the sea is smooth and glassy. They were formed in some place where the wind was high, and have traveled far beyond their place of origin. Such waves are known as *rollers*, or *ground swell*. Because waves travel so far, no part of the open ocean is ever entirely free from some form of wave or swell.

In shallow water the free movement of waves is interfered with by the bottom, the wave grows higher, its front becomes steeper, and it finally topples over (Fig. 327). Then tons of water are hurled bodily forward as *surf* or *breakers* (Fig. 321), striking the shore with tremendous force.

A current, called the *undertow* (Fig. 327), flows outward along the bottom beneath the incoming breakers. On many wave-beaten coasts the undertow is so strong as to be a source of danger to bathers, who are caught by it and held under water.

Some of the rock fragments that are dislodged from cliffs and ground up on the beaches, are moved offshore in the undertow. Others are pushed along the coast (1) by the breaking of waves which reach the coast diagonally, and (2) by the slow wind-formed surface current (Fig. 327), which moves in the direction the wind is blowing.

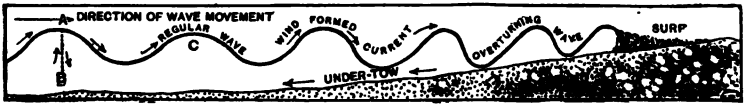


Fig. 327.—Diagram to show approach of a wave upon a beach.

Summary.— *Waves, caused by friction of wind, are a rising and falling of the water, the wave form moving forward, often far beyond the place of origin. They break on the coast with great force, tearing rocks from the cliffs and grinding them on the beaches, moving some of the fragments offshore in the undertow, some along the coast.*

134. Other Waves.—Tap lightly on the bottom of a pan of water, and the water rises in a low dome. An earthquake shock in the ocean produces a similar wave, reaching from the bottom of the sea to the surface. The water may not be raised more than a fraction of an inch, but the disturbance is so deep and affects so much water that, when the wave approaches a neighboring coast, it rises higher and higher. Such a wave may then rise to a height of more than 100 feet, rushing perhaps a mile or more inland, carrying everything before it, and leaving vessels stranded (Fig. 322). Tens of thousands of people have been drowned by a single earthquake wave (p. 119).

Fortunately such waves are not common in many parts of the world, though Japan, the East Indies, and the coast of Chile and Peru are subject to them. The waves travel great distances, some from Asia reaching the California coast; but, so far away, they are too much spread out to be destructive.

The discharge of an iceberg from a glacier (p. 145), or the breaking up of an iceberg as it runs aground, starts a similar

FIG. 328. — High tide near Bourne, Mass.

FIG. 329. — Low tide at same place as above. Describe the difference.

FIG. 330. — Low tide at Gloucester harbor, Mass., where the tide rises 8 or 10 feet. At high tide a fishing schooner (Fig. 341) can come in beside the wharf.

FIG. 331. — Low tide along the coast north of Boston, showing the seaweed mat which covers the rocky coast, protecting it from wave attack. At high tide the water reaches above the dark-colored zone of seaweed.

wave. These iceberg waves dash on the shores with great force, reaching several feet above the normal level of the waves.

A wave of high water accompanies hurricanes and other violent storms at sea (p. 271).

Summary. — *Waves are also started by earthquake shocks on the ocean bottom; by the breaking off or stranding of icebergs; and by violent storms at sea.*

135. Tides. — Twice each day (more exactly, every 12 hours, 26 minutes) the passage of tidal waves, formed by the attraction of moon and sun (Appendix E), causes the ocean surface to rise and fall (Figs. 328, 329). In the open ocean the difference in height between high and low tide, or the *tidal range*, is not over one or two feet; but, as the tidal wave approaches the coast, its height is increased (Figs. 330, 331) by the effect of the shallowing bottom.

In the ocean, and on open coasts, the tide is merely a rise and fall in the water level; but in bays and estuaries this change in level starts currents, which often move with great velocity. Such currents may move so rapidly that boats cannot make headway against them; indeed, in the Bay of Fundy the tide advances over the mud flats more rapidly than a man can run. From this it is evident why, as the tide rises and falls, it is said to "come in" and "go out." The rising tide is called the *flow*, the falling tide the *ebb*.

The advancing tidal wave is greatly influenced by the form of the coast. Ordinarily the tidal range is between 3 and 10 feet; but in narrowing, V-shaped bays the range is greatly increased, as in the Bay of Fundy in Nova Scotia and Ungava Bay in northern Labrador, where the tide rises from 30 to 50 feet.

On the other hand, where bays broaden out, bag-shaped, the tidal range is greatly diminished. For instance, the Atlantic tide, passing through the Straits of Gibraltar, produces practically no effect on the broad Mediterranean; but a very small local tide is developed in the Mediterranean itself. This almost complete absence of tide in the Mediterranean was of great impor-

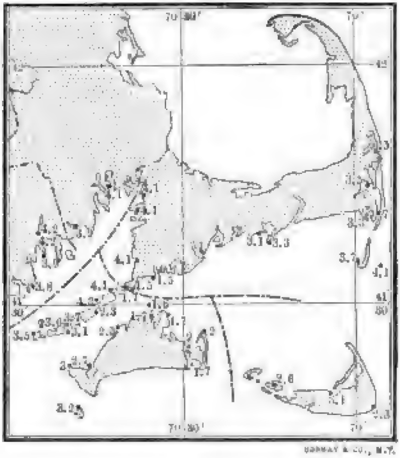


FIG. 332. — Range of tide, south of Cape Cod, indicated by figures. In Buzzards Bay it rises 4.1 feet; in Vineyard Sound, from 1.5 to 3.1; consequently rapid currents, or races, pass through gaps between the islands that separate the two bodies of water.

tance in the development of navigation in that inclosed sea (p. 377) and the growth of nations along its shores. With strong tidal currents to battle against, the movement of their small, open boats, propelled by oars, would have become a much more difficult task.

Along irregular coasts there are bays where the tidal range is greater than in neighboring parts of the coast. If there happens to be connection between two such places, rapid tidal currents, or *races*, will pass through the connecting straits. An illustration of this is found in southern Massachusetts, where rapid currents flow between Buzzards Bay and Vineyard Sound (Fig. 332). A similar current occurs at Hell Gate, in the narrow strait between New York Bay and Long Island Sound (Figs. 333, 334).

On entering some river mouths the tidal current changes to a wave, known as the *bore* (Fig. 323), which travels rapidly upstream. It is found in the Seine, Severn, Amazon, and several other rivers.

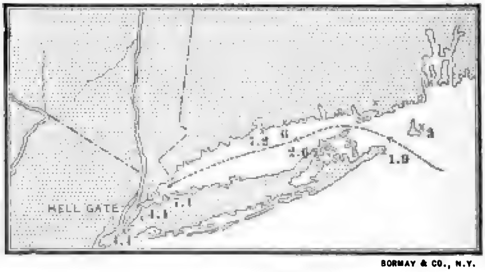


FIG. 333. — The height to which the tide rises on the two sides of Hell Gate, over which there are rapid tidal currents.

Not only does the tide vary from place to place, but also from time to time. At new and full

moon the tidal range is greater than during the quarters. Tides with high range are known as *spring* tides, those with low range, *neap tides* (Appendix E). The correspondence of spring and neap tides to phases of the moon, and the fact that two complete tides occur every 24 hours, 52 minutes (the period between two moonrises), long ago led to the discovery that the tides are due to some influence of the moon.

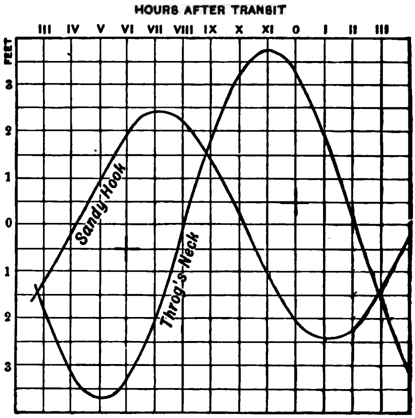


FIG. 334.—Diagram to show time of arrival and height reached by the tides on the two sides of Hell Gate. The currents at Hell Gate are therefore due to two causes: (1) the time of high tide differs on the two sides; (2) the tidal range differs.

Tides are of great importance along the coast. The tidal currents drift sediment about, thus helping to form sedimentary strata (p. 32). They also deposit sediment in harbors, and each year large appropriations are necessary for the purpose of removing such deposits. By these currents, too, a circulation is caused in harbors (Fig. 330), thus helping to remove the filth that necessarily finds its way into the ocean near large cities.

Tidal currents aid or impede vessels, according to their direction; and they sometimes drift vessels from their course, placing them in dangerous positions. Every now and then in foggy weather, when the land cannot be seen, vessels run aground, because the tide has drifted them out of their course. The captains of all large ships carry tide tables and charts to aid them in navigation. One use of these is to tell when the tide is high, for the entrances to many harbors are too shallow to admit large ships at low tide.

Summary. — *Every 12 hours, 26 minutes, the ocean surface rises and falls with the passage of a tidal wave. In the open ocean the range is a foot or two; along the coast from 3 to 10 feet; in V-shaped bays even 30 to 50 feet; but in large bays that broaden, the tide may be destroyed. Along irregular coasts the rise and fall of the tide cause currents, which may become very rapid races. Tidal currents move sediment about, helping to deposit sedimentary strata; they drift sediment into harbors; they keep the harbor water in circulation; they aid or impede navigation; and they sometimes place vessels in dangerous positions.*

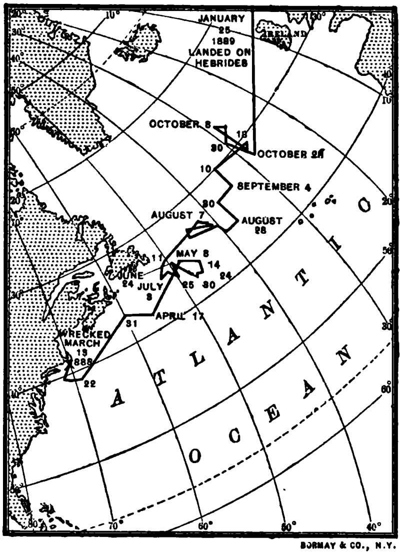


FIG. 335. — The drifting of a wreck from March 13, 1888, till it went ashore January 25, 1889. Storm winds now and then caused the wreck to leave its general course in the ocean drift.

136. Ocean Currents. — The ocean waters are in constant circulation, not only along the bottom (p. 184), but also in well-defined surface currents (Fig. 335). The existence of ocean currents has been known for a long time; indeed, Columbus noticed them along the American coast, and Benjamin Franklin studied them and considered them the result of steadily blowing winds. It is now known that there are currents slowly sweeping through each of the oceans (Fig. 338).

Differences in temperature of the ocean water account for the settling of water in cold regions and its circulation along the sea bottom (p. 184). But it does not seem an adequate explanation for the surface currents.

The explanation that best accounts for surface currents is the effect of steadily blowing winds, as suggested by Franklin. By blowing on a pan of water with sawdust floating in it, a drift of water is seen to start; in like manner, winds blowing over lakes or ocean start a similar drift of surface water. Such wind-drift currents continue to move for some time after the wind dies down.

A comparison of the ocean-current chart (Fig. 338) and the wind chart (Fig. 408) shows that there is a close resemblance between the direction of ocean currents and regular winds. We will study the currents of the Atlantic Ocean to see how close this relationship is.

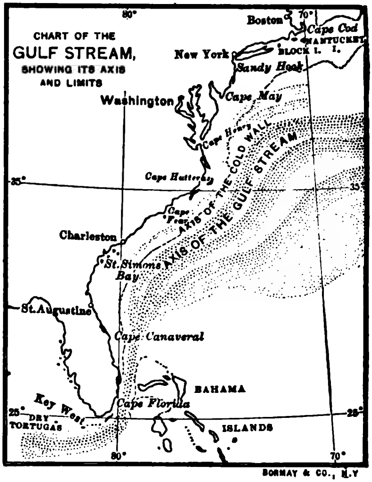


FIG. 336.—The Gulf Stream.

In the equatorial region there is a *drift*[1] of water, the *Equatorial Drift*, toward the South American coast. At the angle of South America it divides, the smaller portion going into the South Atlantic, the larger into the North Atlantic. This Equatorial Drift is exactly what we would expect to find, for the northeast and southeast trade winds blow steadily day after day, drifting the water westward before them.

After dividing on the coast of South America, the drift follows the coast for a while, then slowly swings to the right in the northern hemisphere, and to the left in the southern.[2]

[1] A slow current may be called a *drift*, a more rapid current a *stream*.

[2] This swinging is caused by the effect of the earth's rotation, which deflects all moving bodies, whether wind or water currents, from a straight course. In the northern hemisphere the moving body is turned to the right, in the southern hemisphere to the left.

Thus a great, slowly moving eddy is formed in each ocean. Floating seaweed (*Sargassum*) accumulates in the center of the eddy in such abundance that it has been called the *Grassy*, or *Sargasso*, *Sea*. Columbus encountered it, and his sailors, not knowing what it was, feared that the ships would run aground in it.

A portion of the *North Equatorial Drift* enters the Caribbean Sea, part coming out between the West Indies, part continuing on into the Gulf of Mexico (Fig. 337). The portion that enters the Gulf is warmed still more in that inclosed sea, and escapes, between Cuba and Florida, as a narrow and rapidly moving stream of warm water, known as the *Gulf Stream* (Figs. 336, 337). On the Florida coast it has a velocity of 4 or 5 miles an hour. The Gulf Stream rapidly broadens, a part of it joining the great *North Atlantic Eddy* that circles in the open ocean outside of the West Indies. This portion returns to once more form a part of the Equatorial Drift.

FIG. 337.—Diagram to show the currents of the western North Atlantic. Figures tell rate of movement in miles per hour.

A smaller portion of the Gulf Stream water, and some of the North Atlantic Eddy, drifts on into the region of the west winds, which drive it on toward the coast of northern

Europe, as the *West Wind Drift.* Thus water, warmed in the equatorial region, the Caribbean Sea, and the Gulf of Mexico, is carried to the European coast, and even into the Arctic. There is no similar stream in the South Atlantic, because there are no partly closed seas for the drift to enter.

Study the currents of the Pacific to see if the same great eddies are found there. Notice that in the Southern Ocean, where there are no continents to turn the currents, the West Wind Drift extends completely around the globe.

Besides these eddies, there are special currents, one of which, the *Labrador Current,* is of great importance to America. This is a cold current, descending from among the islands of the Arctic along the Labrador, Newfoundland, and New England coasts (Fig. 337). It keeps close to the American shores, being turned to the right by the influence of rotation. Thus, while warm water is drifted toward Europe, cold water flows down the American coast as far south as Cape Cod, where it disappears by settling and mingling with the warm water.

Summary. — *The surface currents are due to the drifting of water before steadily blowing winds. In each ocean there are great eddies, started by the trade winds, which cause an Equatorial Drift toward the west. This, dividing on the continents, follows the coast northward and southward for a while; then it is turned, by the effect of rotation, to the right in the northern hemisphere and to the left in the southern. Thus an eddy is caused in each ocean, both north and south of the equator. A part of the North Equatorial Drift enters the Gulf of Mexico and emerges as the warm Gulf Stream, a portion of which joins the eddy of the North Atlantic. A portion of the eddy, and of the Gulf Stream, is drifted by the west winds to the European coast, and even into the Arctic. In the southern hemisphere the West Wind Drift extends around the earth. The cold Labrador Current sweeps down the American coast from the Arctic, and, being turned to the right, is forced to hug the coast till it sinks.*

137. Effects of Ocean Currents. — The most important effect of ocean currents is on climate (p. 278). For instance,

the warm water that is borne into the Arctic by the West Wind Drift, influences the temperature of northern Europe. Its effect was very well shown by Nansen's voyage toward the pole. He started into the Arctic north of Scandinavia, where the warm drift keeps the sea fairly clear of ice in summer (Fig. 338), and was able to push his ship far into the Arctic before he met with impassable ice.

Ocean currents aid or retard vessels, according to their direction; and, in their reckonings, navigators must make allowance for this influence. Columbus had much difficulty in navigating his small ships among the currents along the northern coast of South America. Currents have other important influences, for example, causing fogs (p. 247), drifting sea ice and icebergs, and bringing oxygen and food for many sea animals (pp. 196, 197).

Summary. — *Ocean currents affect climate, influence the movement of vessels, and are further important in causing fogs, drifting sea ice and icebergs, and bearing oxygen and food for sea animals.*

138. Ice in the Ocean. — Each winter a large part of the Arctic Ocean is frozen over, often to a depth of 5 or 10 feet. The tidal currents move the ice about, opening cracks or *leads*, and closing them again with such irresistible force that the ice is broken and piled up in ridges of *pack ice* often 50 or 100 feet high. More than one Arctic ship has been crushed like an eggshell between these moving ice fields.

Nansen, Abruzzi, and Peary have all tried to reach the North Pole over this frozen sea; but the many leads, and the irregular surface of the ice packs, have proved such barriers to progress that no one has yet succeeded in reaching the pole.

In summer the ice breaks up, and the fragments drift southward till they melt. Each spring and early summer there is a steady stream of these ice fragments, or *ice floes*, passing down the Labrador coast in the Labrador current (Fig. 340).

Icebergs, discharged from the ice sheets of Greenland and other northern islands (p. 145), also drift in the Arctic waters (Fig. 339). They are huge floating islands of ice, sometimes rising more than

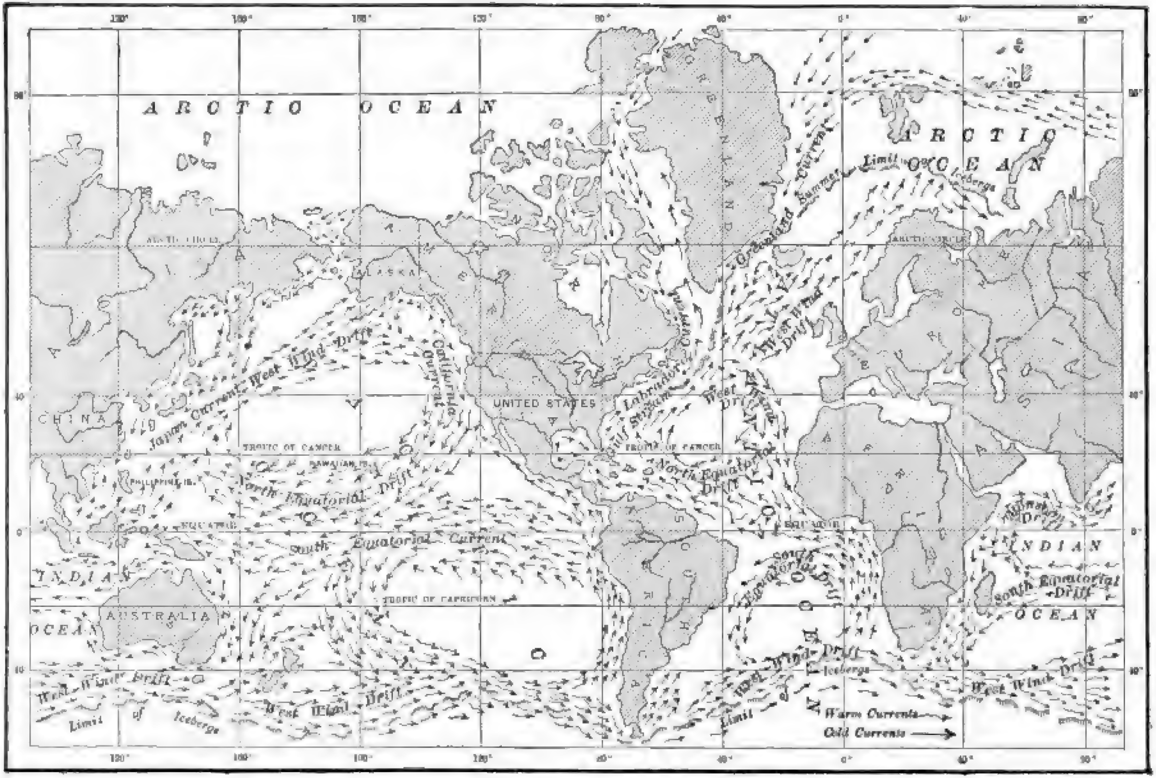


FIG. 338. — A chart showing the principal ocean currents and ocean drifts of the world. Study this map carefully. Make a sketch map somewhat like it. Compare the direction of the currents with that of the winds in Fig. 408.

FIG. 339. — Glacier ice in Greenland (near Fig. 264), the Cornell glacier being directly opposite. The ice cliff, Fig. 265, is just over the boat.

FIG. 340. — Sea ice in summer in the Labrador Current off the coast of Baffin Land. The ship was held here for several days, then the ice was opened by tidal currents and the ship was able to leave.

100 feet above the water. Since ice floating in salt water has about seven parts below water to one above, some of these bergs extend 700 or 800 feet beneath the surface. They frequently run aground (Fig. 267), either breaking to pieces by the shock, or remaining aground till melting allows them to float away. So huge are these bergs that, before melting entirely, they may travel 1000 or 2000 miles, even down to the path followed by ocean liners. They are much dreaded, for even the largest ship may be destroyed by running into one.

Far greater icebergs are discharged from the Antarctic ice sheet, some of them rising 500 feet above the water and, consequently, measuring three quarters of a mile from base to top. They have steep sides and flat tops, and are sometimes several miles long.

Summary. — *The Arctic sea-ice, formed in winter, breaks up in summer, some of it drifting southward in the Labrador current. Huge icebergs, discharged from the Greenland ice sheet, drift in the Arctic, and still larger ones in the Antarctic.*

LIFE IN THE OCEAN.

139. Surface (Pelagic) Life. — The abundance of life in the ocean is marvelous. A pail of water dipped from the surface will contain thousands of individuals, mostly microscopic. These organisms are drifted about by winds and currents, and with them are many larger forms, some merely floating, some swimming. Pieces of floating wood have animals attached to them; and in the floating seaweed, many animals live in little worlds of their own.

The minute organisms are the source of food for many larger animals, even for the huge whales. Swimming with its mouth open, the whale strains the water to obtain its food, and thus the largest of animals feeds upon the smallest.

Among the many fishes are some, like the mackerel, which are valuable for food supply. For protection, the mackerel and some other fishes swim together in vast numbers, forming "schools" or "shoals."

Summary. — *Life is very abundant in the surface waters, both large and microscopic forms being present, the latter serving as a food supply for even the largest of animals, the whale.*

140. Life along Coasts (Littoral). — Along the coast line there is also abundant animal life; but it is more varied than in the open ocean, because the coast offers so many different conditions. Some of the littoral animals swim in the surf; others cling to the rocky coast; and others burrow in the sand or mud. Many kinds, such as clams, oysters, lobsters, and a large number of fishes, are valuable as food; others, such as sponges, precious corals, and pearls, are of value for other purposes.

Plants, as well as animals, abound on the seacoast. This is true in the mangrove swamps of the tropical zone (Fig. 379) and the salt marshes of the temperate zones (Fig. 378); it is also true of rocky coasts, to which seaweeds cling, covering the rock with a mat of plant growth (Fig. 331).

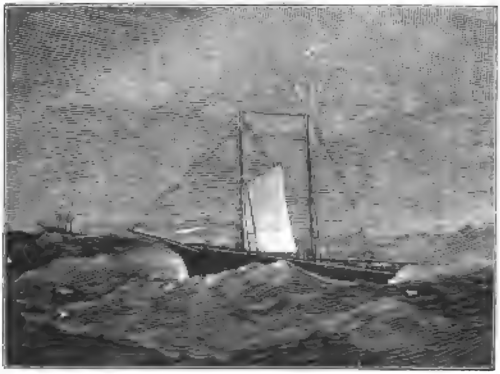


Fig. 341. — A Gloucester fishing schooner anchored on the Fishing Banks.

Some conditions are unfavorable to littoral life; for example, (1) frequent earthquake shocks, (2) the grinding of Arctic sea-ice, and (3) the grinding of moving sand and pebbles on the beaches. Other conditions are very favorable, especially the presence of food-bringing currents. Few parts of the earth have such an abundance and variety of animal life as the coral reefs (Fig. 380), which are bathed by warm ocean currents.

The influence of food-bringing currents is felt on those shallow banks, known as *fishing banks*, where large numbers of food fish live. This is well illustrated on the fishing banks off northeastern America, such as Georges and the Grand Banks of Newfoundland, which are bathed by the Labrador current. These are resorted to for cod, haddock, and halibut by fishing vessels from France, Newfoundland, Nova Scotia, and many New England ports, especially Gloucester, Mass. From a passing ocean liner, the schooners may be seen at anchor in the open ocean (Fig. 341), the men busily fishing, either from the sides of the vessel or from small, open dories. It is a hazardous calling, and many a fishing vessel has been sunk during the fierce storms, or crushed by the huge transatlantic liners. Every year, also, men in dories are separated from their vessels during fogs, which are frequent on the banks. They then drift about in the open ocean, often until they starve, or freeze, or founder.

Summary. — *Animal life along the coast is abundant and varied; there is also much plant life. Food-bringing currents especially favor life, as is illustrated on coral reefs and fishing banks, from which valuable food fish are obtained.*

141. Life on the Ocean Bottom (Abyssal). — Absence of sunlight prevents the existence of plant life in the deep sea; but, even at depths of two or three miles, there are animals on the ocean bottom (p. 174). These animals live in darkness, in water almost at the freezing point, and under a pressure of many tons.

Fig. 342. — A deep-sea fish.

The conditions on the ocean bottom are very uniform: summer and winter are alike; day and night are dark; everywhere it is cold; and the sea floor is a monotonous expanse of ooze or clay. The nature of animal life varies with the depth because of differences in temperature; and where the water is very cold, animals are scarce and have little vitality. The supply of

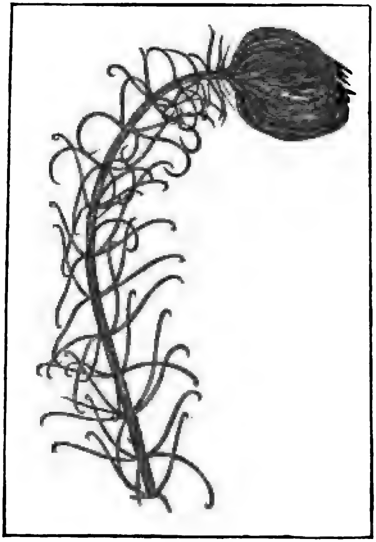


FIG. 343.—A stalked crinoid from the deep sea.

oxygen, brought by the slowly moving bottom current (p. 184), and the supply of food, which settles down to the bottom as organisms at the surface die and slowly sink, also limit abyssal life.

Under such uniform conditions it is not strange that many strange forms of animal life should be found in the deep sea. Some of them, like the stalked crinoids (Fig. 343), belong to types once abundant, but now living only on the ocean bottom. There they have been able to survive, as in an asylum, while those which were out in the world, and exposed to the struggle that goes on there, have been exterminated.

Summary. — *There is wonderful uniformity of conditions in the deep sea, in which animals, but no plants, live. The abundance and distribution of animal life are influenced mainly by temperature, oxygen supply, and food supply.*

TOPICAL OUTLINE, QUESTIONS, AND SUGGESTIONS.

TOPICAL OUTLINE. — 124. **Oceanography.** — Definition; exploring expeditions; cables; sounding; water samples; ocean-bottom mud; temperature; dredging.

125. **Ocean Basins.** — General condition; deep-sea plains; deeps; elevations; Atlantic, — deepest point, volcanoes, mid-Atlantic ridge; Pacific, — volcanic chains, deepest point, other deeps; Arctic; Southern Ocean.

126. **Deposits on the Ocean Bottom.** — (A) *Rock fragments:* source; deposit; fossils. (B) *Ocean-bottom oozes:* absence of rock waste; area of ooze; materials in ooze; source of organisms; globigerina ooze; pteropod ooze; diatom ooze. (C) *Red clay:* solution of shells; insoluble parts; red color; slowness of accumulation; proofs.

127. **Land and Ocean-bottom Topography.** — Mountain folding and volcanic action; erosion; sediment; result of differences.

128. **Surface of the Sea.** — Sea level; effect of continents; of winds and storms; of deposit of sediment; of sinking ocean bottom.

129. **Composition of Sea Water.** — Original condition; increase in saltness; proportion of salt; other mineral substances; amount of salt; importance; carbonate of lime; presence of air; importance.

130. **Density and Pressure of Sea Water.** — (*a*) Density: average density; effect of fresh water; of evaporation. (*b*) Pressure: amount; reason for no effect on animals; animals brought to the surface; density of ocean-bottom water.

131. **Color and Light.** — (*a*) Color: entrance of sunlight; blue color; green color; Yellow River; Red Sea. (*b*) Light: darkness of ocean bottom; blind fish; phosphorescence on ocean bottom; at the surface.

132. **Temperature of the Oceans.** — From tropical to frigid zones; inclosed seas; decrease downward; ocean bottom; cooling of fresh and salt water; circulation; effect on animals; inclosed sea bottoms.

133. **Wind Waves.** — Cause; nature of movement; height; crest; trough; whitecaps; rate of movement; effects on vessels; use of oil; rollers; breakers; undertow; movement of rock fragments.

134. **Other Waves.** — Earthquake waves, — cause, size, effects, occurrence, distance of travel; iceberg waves; hurricane waves.

135. **Tides.** — (*a*) Nature of tides: time of passage; tidal range; increase on coast; movement in open ocean; currents on coast; flow; ebb. (*b*) Influence of coast: ordinary range; effect of V-shaped bays; of broadening bays; Mediterranean; races; examples; bore. (*c*) Influence of moon's phases: spring tides; neap tides; relation of tides to moon. (*d*) Effects of tides: on deposit of strata; on deposits in harbors; on circulation of water in harbors; on navigation.

136. **Ocean Currents.** — Early knowledge; effect of temperature differences; of steady winds; resemblance between winds and currents; a drift; a stream; Equatorial Drift; effect of continents; effect of rotation; Sargasso Sea; Gulf Stream; North Atlantic Eddy; West Wind Drift; Pacific eddies; West Wind Drift of Southern Ocean; Labrador Current; compare European and American coasts.

137. **Effects of Ocean Currents.** — Climate; Nansen's journey; effect on navigation; fog; ice; oxygen and food.

138. **Ice in the Ocean.** — (*a*) Sea ice: depth; leads; pack ice; travel over the ice; ice floes. (*b*) Icebergs: source; size; grounding; distance traveled; Antarctic bergs.

139. **Surface (Pelagic) Life.** — Abundance; modes of life; whales; mackerel.

140. **Life along Coasts (Littoral).** — Varied conditions; valuable animals; plant life; unfavorable conditions; favorable conditions; fishing banks, — location, food fish, fishing, dangers.

141. **Life on the Ocean Bottom (Abyssal).** — Plants; animals; surroundings; temperature; oxygen; food; survival of types.

QUESTIONS. — 123. In what ways is the ocean of importance?

124. What is oceanography? What expeditions have been engaged in deep-sea exploration? How is the depth of the sea learned? What facts are learned during a sounding? How is dredging carried on?

125. What is the condition of the ocean bottom? What irregularities occur? What irregularities are found in the Atlantic? In the Pacific? What is known of the Arctic and Southern oceans?

126. (A) What is the nature of the deposit near the coast? (B) Why is ooze deposited far from land? Of what is it composed? (C) What is the origin of red clay? Prove that it is forming slowly.

127. Why are land and ocean-bottom topography different?

128. What is sea level? How is this level changed?

129. What is the origin of the mineral substances in sea water? What mineral substances are there? How much salt is there? Of what importance is the carbonate of lime? The air?

130. What causes water to vary in density? What is the pressure on the ocean bottom? Why do not animals feel it? What would be the condition if the ocean-bottom water were compressed like the air?

131. What causes are there for the different colors of the ocean? What light is there on the ocean bottom?

132. What causes differences in temperature of the ocean-surface waters? What are the temperature conditions below the surface? Why is the bottom temperature lower than that in lakes? What is the cause of the slow circulation? What proof is there of it?

133. What causes waves? What is the real movement of the water? What causes whitecaps? How high may waves be? How fast may they move? What damage may they do to ships? How may this danger be lessened? What is the cause of rollers? What causes breakers? What is undertow? How are rock fragments carried away?

134. What causes earthquake waves? What are some of their effects? What other causes are there for waves?

135. To what height does the tidal wave rise? Under what conditions are tidal currents formed? What is flow? Ebb? What happens as tides enter narrowing bays? Where they enter broadening bays? Give an illustration. What causes tidal races? Give illustrations. What is the bore? What reasons are there for connecting tides with the moon? Name some important effects of tides.

136. What early knowledge of ocean currents was there? What effect have differences in temperature on ocean movements? What effect has the wind? Describe the system of currents in the Atlantic Ocean, and show how it is related to winds. Describe and explain the Gulf Stream. What is the Sargasso Sea? What currents are found in the Pacific? Other oceans (Fig. 338)? Describe the Labrador Current.

137. Name the important effects of ocean currents.

138. What are the characteristics of sea ice? Describe the icebergs of the Arctic. Of the Antarctic.

139. What are the conditions of pelagic life?

140. How do the conditions surrounding littoral life vary? In what situations are littoral plants found? What conditions oppose littoral life? What conditions favor it? Why are fishing banks the home of food fish? What dangers accompany the fishing?

141. What conditions influence life on the ocean bottom?

SUGGESTIONS. — (1) Prove that salt water is more dense than fresh, by putting shot in a bottle until it will barely sink in fresh water, taking care to cork it; then dissolve salt in the water and again put the bottle in it. (2) Cut a cube of ice and place it in fresh water. Measure the amount above and below water. Place it in salt water and measure again. What is the result? (3) In a large pan, or tub, of water place a bottle, partly submerged. Start waves by blowing on one end. Note how they travel beyond their source. Note the movements of the bottle as the waves pass under it. Have the students describe its movements. At one end of the pan make a shelving beach of sand, with a cliff at one end. Observe and describe the action of the waves as they approach the shore. What differences are there in the behavior of the waves on the beach and on the cliff? Are fragments removed? Where do they go? Make waves that advance diagonally on the shore and observe the movement of the fragments. To see this clearly, place at one point some colored objects, like bits of colored glass, and note how they move. (4) In the pan build a coast, roughly like that of North and South America. Sprinkle sawdust on the water and blow over its surface from both sides of a line (the equator), to imitate the trade winds approaching the equator. Watch the drift of water. Do you see any resemblance to the ocean-current systems of the Atlantic? (5) Take the temperature at the bottom of the pan near the middle line, then place ice in the water as far away from the middle as possible. Be careful not to stir the water. After the ice has melted, again take the temperature under the middle line. What is the difference? It would be possible also to imitate the conditions in the Gulf of Mexico (p. 184). (6) If the school is by the sea, or even near a lake or pond, waves and wind-formed currents should

be studied. Note their force, form, and effects. (7) If by the seashore, the tides should be studied. Observe time of low and high tides for three successive days. These facts may be obtained from an almanac, or better, from the *Tide Tables* published by the U. S. Coast Survey at Washington, the tables for the year, for the Atlantic (15 cents) and Pacific (10 cents) coasts. Observe the time of spring and neap tides. How do they compare with the phases of the moon. What is the range of the tide in each case? Are there any tidal currents near at hand? Are the tides of any importance in your harbor? That is, do they do any harm or good? (8) On cross-section paper, plot a curve to represent the high and low tide for a month (obtaining the facts from the Tide Tables). Let each of twelve students do a different month and then paste them all together. Above the curves indicate each quarter of the moon. Have the students study these to see how closely the phases of the moon coincide with variations in range of the tide. Let the vertical side of each square represent a foot of tidal rise, and the horizontal side, three hours of time. (9) On an outline map of the world sketch the ocean currents from the chart in the book (Fig. 338).

Reference Books. — THOMSON, *Depths of the Sea*, 2 vols., Macmillan Co., New York, 1873, $7.50; *The Atlantic*, Macmillan & Co., London, 1877 (out of print); AGASSIZ, *Three Cruises of the Blake*, 2 vols., Houghton, Mifflin & Co., Boston, 1888, $8.00; WILD, *Thalassa*, Marcus Ward & Co., London, 1877, 12 shillings; MOSELEY, *Notes by a Naturalist*, Murray, London, 1892, 9 shillings; SIGSBEE, *Deep Sea Sounding and Dredging*, U. S. Coast Survey, Washington, D.C., 1880; TANNER, *Deep Sea Exploration*, p. 1, 1892 Report, U. S. Fish Commission, Washington, D.C.; DARWIN, *The Tides*, Houghton, Mifflin & Co., Boston, 1898, $2.00; *Tide Tables for the Year*, U. S. Coast Survey, Washington, $0.25; PILLSBURY, *The Gulf Stream*, Annual Report, U. S. Coast Survey for 1890, Appendix 10, Washington, D.C.

CHAPTER XI.

SHORE LINES.

142. Importance of Shore Lines. — Some of the busiest centers of human industry are located on or near the seacoast. The great and increasing trade that uses the ocean as a highway converges toward these centers; and to and from them, by river, canal, and railway, there is a steady movement of goods for shipment or for distribution.

So important is the coast line that charts have been made of all parts of it that are reached by the vessels of commerce. Governments maintain bureaus, like the United States Coast Survey, whose duty it is to map the coast, to determine by accurate soundings the depth of water, and to detect and record all changes, such as shifting of channels, which might endanger ships. In addition, our government annually spends large sums of money for the improvement of harbors. This money is used in building breakwaters where no natural harbors exist; in dredging out the sand and mud that waves and currents deposit; and in building jetties and other structures to control the deposits of sediment and keep channels clear.

The approach to the coast, especially in times of storm and fog, is accompanied by so many dangers — from hidden reefs, islands, and projecting headlands — that all civilized nations spend large sums in the effort to lessen these perils. To warn sailors, or to guide them into port, lighthouses are built on exposed points and light-ships anchored on dangerous shoals; and, on the charts, the location and characteristics of these lights are shown. On approaching the coast at night, the first sign of land is the gleam of the lighthouse; and by the color, brilliancy, nature of

flashes, or other device, the mariner knows his position. During fogs and stormy weather a fog-horn adds its warning note.

Specially trained pilots are licensed to guide ships into port; and buoys are placed at frequent intervals to mark the channel. Some of the buoys, placed over reefs or near dangerous currents, have bells that are rung, or whistles that are blown, by the rocking of the waves, to warn the sailors of danger. Even with all these precautions vessels far too frequently run ashore. To rescue the shipwrecked, life-saving stations are established at frequent intervals by state and national governments; and in them men with strong life-boats, lines, and other life-saving apparatus are ever ready for the call of distress.

The coast line has become of importance to many people as a vacation resort. In summer, when the interior of the country is hot, the seacoast is cool and pleasant; there are rocky coasts to scramble over, beaches to walk upon, surf to swim in, and boating and fishing to enjoy. Consequently, tens of thousands of people go to the seashore for a part or all of the summer.

Summary. — *The seacoast is the site of some of the busiest centers of human industry. It is so important that it is charted; harbors are built or dredged out; lighthouses, buoys, and other warnings and guides are placed along it; and life-saving stations are established. The seacoast is also an important summer resort.*

143. The Seacoast is ever changing. — Waves and currents are vigorously at work, wearing away the land (Fig. 347) and moving rock fragments to places of deposit; and rivers are ever pouring sediment into the sea. Along some coasts the waves are cutting back the cliffs (Fig. 344) at the rate of one or two feet a year (Fig. 358), as on the outer shore of Cape Cod and Martha's Vineyard. In other places, deposit is building out the coast, especially near river mouths (Fig. 345). Pisa, in the Middle Ages a seaport, is now several miles inland on the delta of the Arno, Leghorn being now the seaport for that region.

Change in level of the land (p. 35), even though slight in amount, produces a difference in the form of the coast.

A slight elevation brings cliffs, beaches, and sea-bottom plains (p. 72) above the reach of the waves; a slight depression, allowing the sea to enter the valleys, entirely alters the outline of the coast. An elevation or depression that in the interior would pass unnoticed, causes such changes in the seacoast that it cannot escape attention.

Since waves are ever at work, since deposits of sediment are always being made, and since the earth's crust is constantly rising or falling, any study of coast lines must be largely concerned with the effects of such changes.

Summary. — *The coast is being cut back by the waves in some places, and built out by deposits in others; and many changes are made by rising or sinking of the land.*

144. Elevated Sea-bottom Coasts. — The uplift of sea bottoms, forming coastal plains (p. 72), produces a low, flat, straight coast line, not generally fitted for dense settlement. Such coasts are found in southern United States, Yucatan, eastern Central America, and Argentina. The land back of the coast is often so level that it is swampy, unhealthful, and unfitted for agriculture.

In tropical lands, as in Central America and Africa, such plains are the seat of deadly malaria. Being made of soft, unconsolidated deposits of clay, sand, and gravel, the soil is often so sterile as to be unsuited to cultivation. Where the soil is fertile and not too damp, however, the level plains make excellent agricultural land; but the lack of good harbors is a handicap to development. Good harbors are rare, chiefly because the contact of the sea with a level plain makes a straight coast with few irregularities.

If a slight sinking occurs, as has been the case in southern United States, the sea enters the valleys, forming bays and harbors; but the harbors are liable to be poor, because the valleys of a coastal plain are shallow. Moreover, the waves and currents, working with loose rock fragments, quickly build sand bars, which skirt the coast, inclosing shallow lagoons, and even extending

across the mouths of bays and harbors (Figs. 372, 373). A constant struggle is, therefore, necessary to prevent their entrances from being choked with sand.

Summary. — *Elevated sea-bottom plains are low, level, straight, skirted by sand bars, and have few harbors, and these mostly shallow and poor, even where sinking of the land has admitted the sea to the valleys. Such conditions do not favor dense settlement.*

145. Straight Mountainous Coasts. — The uplift of sea bottoms is sometimes accompanied by mountain folding. This either raises narrow strips of coastal plain, between the mountains and the sea, or else causes the mountains to rise directly out of the sea. Where the mountains rise from the ocean in long chains of folds, they produce a straight and regular coast line.

Such a coast exists in western America, from Oregon to central Chile (Fig. 346). Along this coast there are few harbors, bays, capes, and peninsulas. In many places the mountains rise directly from the sea; elsewhere at the inner margin of a narrow coastal plain (Fig. 117). The sea bottom slopes rapidly, and, in a short distance from the coast, the water is 15,000 or 20,000 feet deep (p. 20).

This coast has been recently elevated, and, in many places, is still rising. Both in 1822 and 1835 a part of the coast of Chile was suddenly raised 2 or 3 feet; and beaches and sea shells on the mountain slopes prove other recent uplifts.

For several reasons, such coasts are not suited to dense populations and high development of industries. (1) There are so few harbors that a place, even though on the shore, may be a long distance from a shipping point. (2) Between the mountains and the sea there is, at best, only a narrow strip of fairly level land, limiting the resources. (3) The mountains act as a barrier to inland communication, few, if any, large streams breaking across them. Peru and Chile have only recently, and at great expense, opened railway communication across the Andes barrier (Fig. 184). The scattered seaports, therefore, have little country tributary to them.

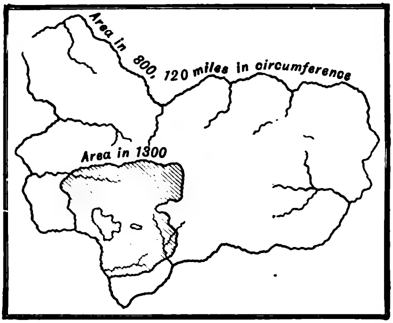


FIG. 344.—Island of Heligoland, in the North Sea. The outer line represents it in the year 800, when its circumference was 120 miles; large shaded area in 1300, circumference reduced by wave erosion to 45 miles; inner shaded area in 1649, circumference only 8 miles.

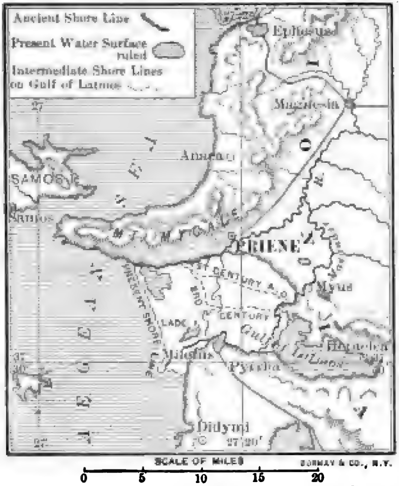


FIG. 345.—Changes in the coast of a part of Asia Minor, by deposits made chiefly by the river Mæander (from which our word "meander" is derived).

FIG. 346.—The straight, mountainous coast of western South America.

FIG. 347.—An old pump on the coast of Ireland, showing how the waves have cut away the land.

FIG. 348. — The Italian coast near Amalfi, showing the houses clinging to the hillside; the road cut and built on the cliff side, and even tunneling through it; and Amalfi itself built on a small stream delta.

Summary. — *Long chains of mountains, rising from the sea, form straight coasts, as in western America. The scattered harbors, the narrow area of level land, and the mountain barrier render such coasts unsuited to dense settlement or high development of industries.*

146. Irregular Mountainous Coasts. — Mountain growth makes irregular coasts more commonly than straight ones. Irregular coasts result (1) when mountains rise as chains of islands near continents, as in the case of the West Indies, East Indies, Philippines, and Japanese Islands; (2) when the ranges extend out from the mainland as peninsulas, as in the case of Italy, Greece, Alaska, and the Malay Peninsula; and (3) when, between mountain ranges, parts of the crust sink, thus admitting the ocean and forming gulfs or seas, like the Gulf of California and the Mediterranean.

The Mediterranean is a broad, deep depression (over 14,000 feet in depth) between the mountains of Europe and Africa. It is almost cut off from the ocean where the Atlas Mountains of Africa nearly meet the mountains of Spain at the Straits of Gibraltar; it is almost connected with the ocean at the low Isthmus of Suez. Its coast line is very irregular, because there are so many short mountain chains, extending in different directions. These form the peninsulas of Tunis, Italy, Greece, and Asia Minor, besides many smaller projections; and also chains of islands, among which Cyprus, Crete, Sicily, the Balearic Isles, and Corsica and Sardinia are the largest. The mountain chain of Italy, extending through Sicily, and along a submarine ridge to the Tunis peninsula, almost cuts the Mediterranean in two.

Many other large seas, such as the Caribbean Sea, Gulf of Mexico, Japan Sea, China Sea, and Red Sea, are partly inclosed by mountain uplifts. Still smaller seas, bays, and even harbors have been made by the uplift of mountainous islands and peninsulas. Where there has been a later sinking, as in Greece, the entrance of the sea into the mountain valleys has made many small bays and deep harbors.

Irregular, mountainous coasts are better fitted for habitation than straight, mountainous coasts. Communication by land is difficult, and the coast line is often steep and rocky (Fig. 348); but the many harbors, the great length of the irregular coast, and the quiet water of the inclosed seas and bays all encourage navigation. It is largely because of these conditions that navigation early developed in the Mediterranean (p. 377). There are many places that, even to-day, can be reached only by ship; and the coasts, as in western Italy, are often so mountainous that a railway, although close by the sea, must pass through a series of tunnels near together. Wherever there is room for towns or villages, as on the delta of a small stream, the coast is well settled (Fig. 348); and, back of the coast, the settlement is especially dense along river valleys that furnish a pathway to the sea.

Summary. — *Uplift of mountainous islands and peninsulas, and sinking of the land between mountain folds, cause irregular coasts. Such coasts, like the Mediterranean, favor navigation because of the number of harbors, the length of the coast, and the quiet water; but they are frequently steep, rocky, and sparsely settled. Communication between places along them must often be by ship.*

147. Coasts of Drowned Lands. — Sinking of the land drowns a portion of it and makes the coast line irregular (Fig. 349), for the valleys are then transformed to bays, harbors, or estuaries. Sinking of the land has made San Francisco harbor (Fig. 350); it has made Massachusetts Bay, Boston harbor, and the other bays and harbors of New England; and it has drowned the lower Hudson (Fig. 351).

When the hills of a drowned land have been completely submerged, shoals and banks (p. 197) are formed in the sea. When the hills are only partially submerged, islands are formed (Fig. 353), like the British Isles, Newfoundland, and the thousands of islands in northeastern (Fig. 354) and northwestern America. Where there has not been submergence enough to completely surround the land, peninsulas are produced, like Scandinavia, Denmark, Nova Scotia, and innumerable capes and promontories (Fig. 354).

FIG. 350. — The harbor of San Francisco, showing the broad bay and the gap made by the Sacramento River in cutting across the Coast Ranges. Into this, sinking of the land has admitted the sea.

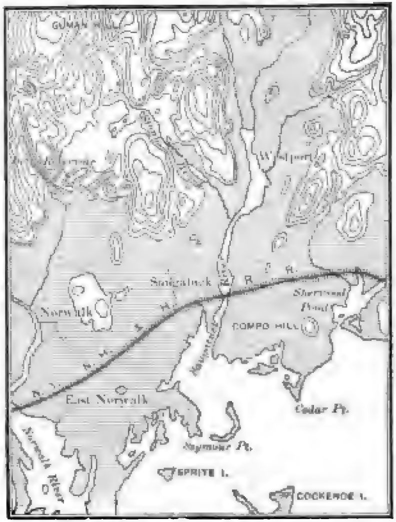


FIG. 349. — The shaded area shows the change in coast outline which would be caused in a part of southern Connecticut if the land should sink 100 feet.

Fig. 351. — The drowned valley of the Hudson, looking north from West Point.

Fig. 352. — A Norwegian fiord.

FIG. 353. — The drowned coast of a part of Norway.

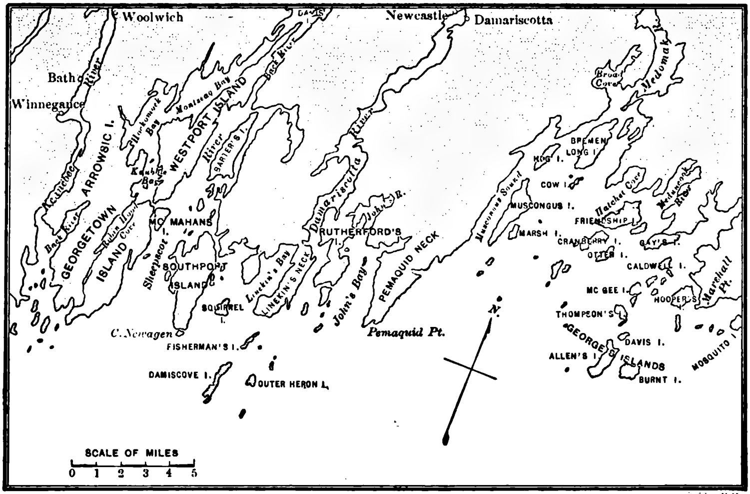


FIG. 354. — A sketch map of a part of the drowned coast of Maine. Measure the distance straight along the coast. Measure it along the greater irregularities.

FIG. 355. — A small bay, or chasm, which the waves have cut in the coast of Cape Ann, north of Boston. Here a narrow dike of trap rock (seen in the middle of the picture) crosses the more resistant granite.

The outline of a sunken coast depends upon the nature of the valleys that existed on the land before it was submerged. Grand fiords, with wonderful scenery, are formed where the sea has entered the deep, steep-sided, mountain valleys of Norway (Figs. 352, 356) and Alaska. These fiord valleys were first cut by streams, then broadened and deepened by glacial erosion. The Hudson is a fiord, and so is the Saguenay in Canada.

FIG. 356. — A Norwegian fiord.

Most fiord coasts, like that of Norway, are too steep and rugged for much settlement. The villages are usually on small deltas, and very often the only communication between them is by water. Such conditions account for the development of that race of hardy sailors, the Norsemen.

The coast south of New York is strikingly different from the rocky coast farther north. This difference is due to the fact that this is a region of soft rock and plains, crossed by broad valleys with gently sloping sides. The entrance of the sea into these has formed broad, shallow bays with gently rising margins, as in Delaware, Chesapeake, and Mobile bays. Along such coasts communication by land is easy and agriculture thrives.

There are several reasons why moderately low, irregular coasts, like those of the Middle States, New England, and England, are favorable to settlement and development. (1) There is an abundance of harbors, — in fact, as in Maine (Fig. 354), often far more than are needed. (2) The irregularity makes a very long coast line for fishing and navigation. (3) There are protected bays and sounds for fishing and navigation. (4) Sinking of the land opens up waterways to the interior. The Columbia, Hud-

son, and Thames are navigable to ocean ships solely because recent sinking has admitted the sea. Portland, New York, and London could not otherwise be important seaports.

The formation of islands cuts off connection with the mainland and produces very important effects on the inhabitants. Thus Newfoundland is so isolated that its interests are different from those of the Canadian provinces, and it has declined to join the Canadian Confederation. The sinking of the land, which separated Great Britain from Europe at the Strait of Dover, has protected the British from inroads of invaders by land, and has forced the development of navigation and a navy (p. 389).

Summary. — *Sinking of the land forms bays, harbors, and estuaries in the valleys, and shoals, banks, islands, and peninsulas of the hills, thus making the coast irregular. The submergence of mountainous regions forms fiords, and a rugged coast suited to navigation, but not to dense settlement. Regions of soft rock, when drowned, have broad, shallow bays with gently sloping sides, adapted to agriculture. Moderately low, irregular coasts favor development because of the harbors, the favorable conditions for fishing and navigation, and the opening of waterways to the interior. The formation of islands isolates people and greatly influences their history.*

148. Wave and Tide Work. — Waves are constantly battering at the coast line, cutting cliffs where possible and moving the fragments about (p. 186). Some of the sediment is dragged offshore by the undertow and tidal currents ; some is drifted along the coast by the waves and the tidal and wind-formed currents. On rocky coasts this shore drift lodges between headlands, forming beaches (Fig. 364) ; on low, sandy coasts it is built into long sand bars (Fig. 372).

Waves and currents are accomplishing two ends by this work: (1) cutting back the land, (2) straightening the coast. An irregular coast will not long be tolerated by waves and currents; and, were it not for the fact that there are so many movements of the crust, the coast lines of the world would all be straight. When, therefore, we find an

FIG. 357. — A wave-cut chasm in the rocks on the Maine coast.

Fig. 358. — A wave-cut cliff in the clay on the shore of Lake Ontario. This cliff is being cut backward at the rate of about two feet a year; and, by this cutting, trees are undermined and caused to slide down the cliff face.

Fig. 359. — A sea cave which the waves have cut on the Maine coast. The dark area in front is the seaweed mat which the high tide covers.

FIG. 360. — A rock cliff on the Maine coast, showing how the waves sometimes undercut, causing the hard rock to overhang. The dark area in the foreground is the seaweed mat, covered at high tide.

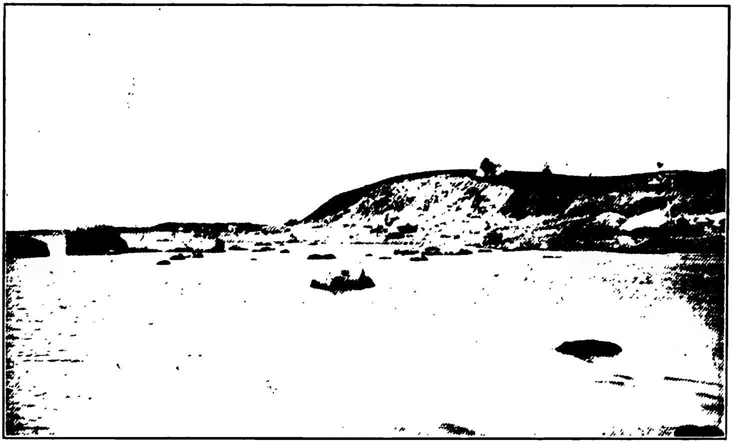


FIG. 361. — A cliff in glacial deposit on the Massachusetts coast. The waves have not been able to remove the large bowlders that were in the deposit, and they, therefore, remain as an offshore platform, showing that the land once extended out that far.

FIG. 362. — A sea cliff on the island of Grand Manan (Bay of Fundy) with a lighthouse on the top. Unconsumed portions of the cliff stand offshore as a platform of reefs. The base of the cliff is skirted with pebbles, with which the waves batter at the cliffs.

irregular coast, we may be certain that the shore has not stood long enough at that level for the waves and currents to straighten it. This work of straightening coast lines is done in two ways — (1) by cutting back the headlands and (2) by closing up and filling the indentations.

Summary. — *Waves and currents are attacking the headlands and moving the fragments either offshore or along the coast, in the latter case building beaches and bars. The result of this work is to straighten the coast.*

149. Sea Cliffs. — Where wave work is vigorous, as on headlands and on exposed island coasts, the waves are sawing into the land (Figs. 344, 347). The zone of most active wave work is almost exactly at the sea level, though the spray may dash to a height of 50 or 100 feet. The advancing breakers hurl against the cliffs tons of water, bearing sand, pebbles, and even bowlders. They act like battering rams, undercutting the cliffs along the surf line (Fig. 360), and thereby undermining the rock so that it falls and keeps the cliff face precipitous.

If made of hard rock, sea cliffs are very steep (Fig. 362), though weathering, aided by the salt spray, usually prevents them from becoming vertical. If made of clay or sand, the cliffs are steeply inclined and constantly sliding down (Figs. 358, 361, 367). On exposed coasts, sea cliffs may rise several hundred feet; but generally they are much lower.

Cliffs in which the rocks have uniform texture may be straight and regular; but if the strata vary, the waves discover the differences and make the shore irregular. Then *chasms* (Figs. 355, 357) and *sea caves* (Fig. 359) are cut in the cliffs along the weaker strata. These irregularities cannot be cut very far back into the land, nor to a very great breadth, because the force of the waves is soon worn out on the sides and bottom. For this reason, waves cannot carve out large bays.

Sea cliffs may be cut back for hundreds of feet, leaving a platform of rock (Figs. 361, 362) which the waves continue to plane

down until they no longer break upon it. In the open ocean entire islands have been cut away by waves (Fig. 234), leaving only shoals or reefs. As the cliffs wear back, farms and houses are undermined and caused to tumble into the sea.

Such headlands, with their offshore platforms, are dangerous to navigation; and a vessel wrecked upon the wave-beaten reefs is doomed. There is little hope that the shipwrecked sailors can escape, for there is no landing place on the cliffs, and the waves are ever breaking on the reefs near their base. It is partly for this reason, and partly because of their height, that headland cliffs are commonly selected as the sites of lighthouses (Fig. 362).

Summary. — *The sawing of the waves into the land cuts sea cliffs, leaving offshore platforms as the cliffs are pushed back. Weathering prevents most cliffs from being vertical, but all are steep, even those in sand or clay. Where there are differences in the rocks, chasms, sea caves, and other small irregularities are produced. Headland cliffs and offshore platforms are dangerous to navigation.*

150. Beaches, Hooks, Bars, etc. — Bowlder (Fig. 363) and pebble beaches (Fig. 364) are built of the larger rock fragments, wrested from the cliffs and driven along the coast, till they lodge in bays. Smaller fragments make sand beaches (Fig. 365); and the still finer clay settles in the protected bays, harbors, and estuaries, forming mud banks and flats. Some fine-grained sands form *quicksands*. In these are numerous particles of mica, which permit the sand grains to slip over one another when wet, so that an object sinks into the sand.

In little pockets between headlands there are often small "pocket" beaches, sometimes called "half moon" beaches, because of their crescentic shape (Figs. 363, 366). Behind them small ponds are often shut in. On exposed coasts these beaches are of bowlders or pebbles; in more protected places, of sand. The beaches serve as mills, in which rock fragments are ground so fine that they can be borne off by the currents and undertow. The rounded form of beach pebbles shows how they are rolled about.

FIG. 363. — A bowlder pocket-beach on the exposed coast of Cape Ann, Mass.

FIG. 364. — A pebble beach on the coast of Cape Ann, Mass. Notice how round the pebbles are. High waves reach clear to the top of the beach.

FIG. 365. — A sand beach, with sand dunes piled upon the landward side by the action of the winds.

FIG. 366. — A crescent beach in a small bay harbor on Santa Catalina Island, Cal. One portion of the cliffs that supply this beach is seen on the right, in the distance. There the waves have not quite consumed the land, but have left a part standing as an island.

FIG. 367. — Highland Light cliff on the back shore of Cape Cod (Fig. 375). This cliff of loose sand is wearing back so fast that little vegetation is able to find root on its slipping face. It is supplying sand for the waves and currents to drift along the coast and build into sand bars and shoals.

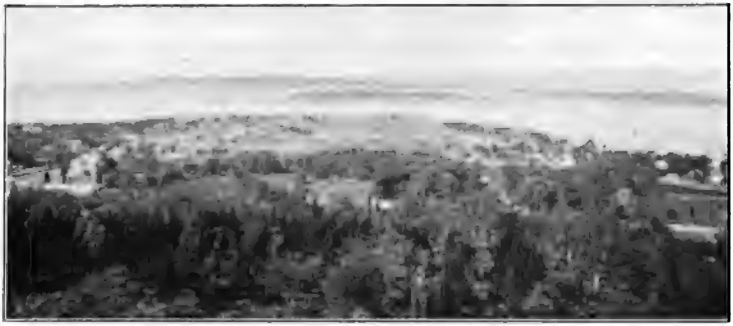


Fig. 368.— A view of the Sandy Hook bar from the Navesink Highlands in New Jersey.

Fig. 369. — A bar joining a small island to the land on the coast of Sicily.

Fig. 370. — A bar at North Fairhaven, N.Y., on the shore of Lake Ontario, partly shutting in a broad bay. The opening is maintained by the outflow of water from the land streams. The pebbles of which this bar is made are supplied from a number of cliffs, of which Fig. 358 is one.

FIG. 372. — Offshore bar on the New Jersey coast. On the mainland, or *old-land*, there is a wave-cut cliff, made before the bar was thrown up (Fig. 387). Now the lagoon between this cliff and the offshore bar, or *new-land*, is being filled with sediment, a part of it being changed to salt marsh. (Atlantic City Sheet, U. S. Geological Survey Topographic Map.)

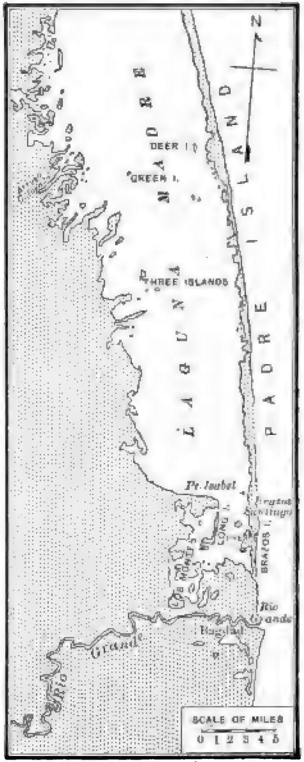


FIG. 371. — Southern part of the long offshore bar which extends northward, from the delta of the Rio Grande, along the Texas coast.

Some of the rock fragments that are moved along the coast are dropped at the entrance to bays, building bars across them (Fig. 373). If there is much drainage from the land, an opening through the bar will be maintained (Fig. 370); but if not, a bar may completely seal a bay (Fig. 373). A fresh-water pond then gathers behind the bar, slowly draining through it by seepage.

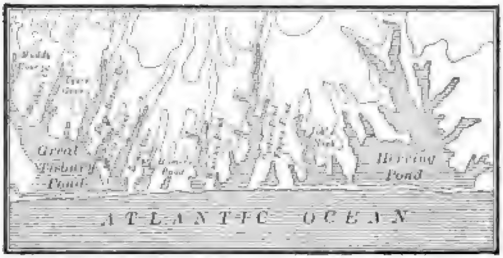


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Fig. 373. — A portion of the south shore of Marthas Vineyard, showing how the growth of sand bars may straighten an irregular coast by shutting in the bays and changing them to ponds.

On many coasts, where there is an abundant supply of sand, long bars are built. For example, the waves are vigorously wearing back the high cliffs (Fig. 367) at Highland Light, Cape Cod, and building bars out of the sand (Fig. 375). In the same way Sandy Hook (Fig. 368) has been built of débris worn from the cliffs of the New Jersey shore.

Such bars may be straight, or they may be curved at one end, forming *hooks* (Fig. 374), like Sandy Hook (Fig. 368) and the curved end of Cape Cod (Fig. 375). In some places, often at bends in the shore, waves and currents from opposite directions drive pebbles or sand out into the water, building small points, or *spits*. Bars sometimes form an angle projecting seaward, making a *cusp*, like Capes Hatteras, Fear, Lookout, and Canaveral. Other bars are often built in the lee of islands (Fig. 369).

Summary. — *Rock fragments, drifted along the coast, build beaches in pockets, bars across bays, long bars where large quantities of sand are supplied; also hooks, spits, and cusps. The material varies from bowlders to sand, much of the fine clay going into the bays. The beaches are mills in which rock fragments are ground up.*

FIG. 374. — A hook in one of the Bras d'Or Lakes (really an arm of the sea) in Cape Breton Island, Nova Scotia. It is made of pebbles driven out into the water by the waves.

151. Offshore Bars. — From New Jersey to the Rio Grande most of the coast is faced by bars at some distance from the mainland, from which they are separated by shallow lagoons (Fig. 372). One of the longest of these bars extends along the Texas coast from the mouth of the Rio Grande (Fig. 371). River water enters the lagoons, some of it seeping through the bar, the remainder escaping through gaps that the outflowing and incoming tide are able to keep open. The movement of sand along the shore constantly threatens to close these channels; and for this reason, where the channels are used as harbor entrances, as at Galveston, it is necessary to build jetties to keep the entrance deep enough for large ships.

Such offshore bars, or *barrier beaches,* are thrown up where waves advance over a shallow bottom of unconsolidated sedi-

ment. The shallowness interferes with the onward movement of the waves, and where they commence to break, the sand is pushed up into a ridge or bar. The wind builds the bars still higher, raising sand dunes (Figs. 376, 377), sometimes 100 feet high. The waves gradually consume the sand bars, eating them away on the seaward side and pushing them back toward the land.

Beaches and bars are often useful as places for landing boats (Figs. 348, 366); and for bathing they are resorted to by hundreds of people. Offshore bars are, in addition, habitable, though usually so sterile that they are inhabited only by fishermen, lighthouse keepers, and pleasure seekers. Yet some bars, like the Sea Islands off the Georgia coast (Fig. 376), where the long-fibered Sea Island cotton is raised, are excellent farm land. Here and there, too, because of the absence of other kinds of harbors on such coasts, towns and cities, like Galveston, are built on the sand bars. The destruction at Galveston in 1900 (Fig. 429) proves that cities in such situations are in danger of inundation.

The sand that is drifted about in the building of sand bars often makes dangerous shoals. The shifting sands south of Cape Cod, and those near Sandy Hook, are obstacles to safe navigation; and, on the shoals at the end of Cape Hatteras, many ships have been wrecked.

Summary. — *Where the waves break on shallow sea bottoms the sand is pushed up into ridges, or offshore bars, which are raised still higher by the wind. Such bars, inclosing lagoons, are found along much of the coast from New Jersey to the Rio Grande.*

152. Sand Dunes of the Seacoast. — On beaches, as in deserts (p. 88), there is dry sand, which the wind drifts about, often piling it up in low hills and ridges, or *sand dunes*, along the upper edge of the beach (Fig. 365). Sand dunes are exceedingly irregular (Fig. 377), and their form is ever changing. Between the dune hills are basins, in which, however, there is rarely any water, because the bottom is so porous.

The movement of sand inland, doing much damage, is sometimes made possible by the removal of a forest, which gives

full sweep to the wind. The removal of a forest back of Coffin's Beach on Cape Ann, Mass., over a century ago, permitted the sand to move inland and destroy a farm. Dunes in France have moved inland two or three miles, destroying farms and villages to such an extent that the French government has taken up the problem of how to stop their further advance. This is being done by planting trees behind the dunes, and setting out such plants as will grow in the sterile, sandy soil.

A sand-dune region is difficult to cross on account of the loose sand, and of little use to man because the soil is so sterile. But in the Netherlands the sand dunes protect the low plains from submergence. The waves are consuming this coast, having cut it back two miles in historic times. As the waves consume the beach the row of dunes behind the beach is slowly pushed inland.

Summary. — *Along many coasts irregular sand hills, or dunes, are built up by the wind, and their advance inland has in some cases caused the destruction of much property. In the Netherlands the sand dunes act as a barrier, protecting the low plains from the waves.*

153. Salt Marshes. — Sediment deposited in estuaries, in lagoons behind sand bars (Fig. 372), and in other protected arms of the sea, is slowly filling them. Salt-water plants that flourish in these places, such as the eel grass and salt-marsh grasses, aid in the filling. Their aid consists partly in adding their own remains, partly in checking the currents, thus causing them to drop some of the sediment they carry.

In time, the deposit of sediment and plant remains reaches to the level of high tide, forming a salt-marsh plain through which extend channels that the tide occupies (Figs. 372, 378). When, by wash from the land, the plain is built higher than the highest spring tides reach, dry-land plants take the place of the salt-marsh plants. By this process, nature is engaged in reclaiming much land from the sea.

Salt marshes are of little value, though a coarse grass, used as bedding for horses, is cut from them. Where dikes have been

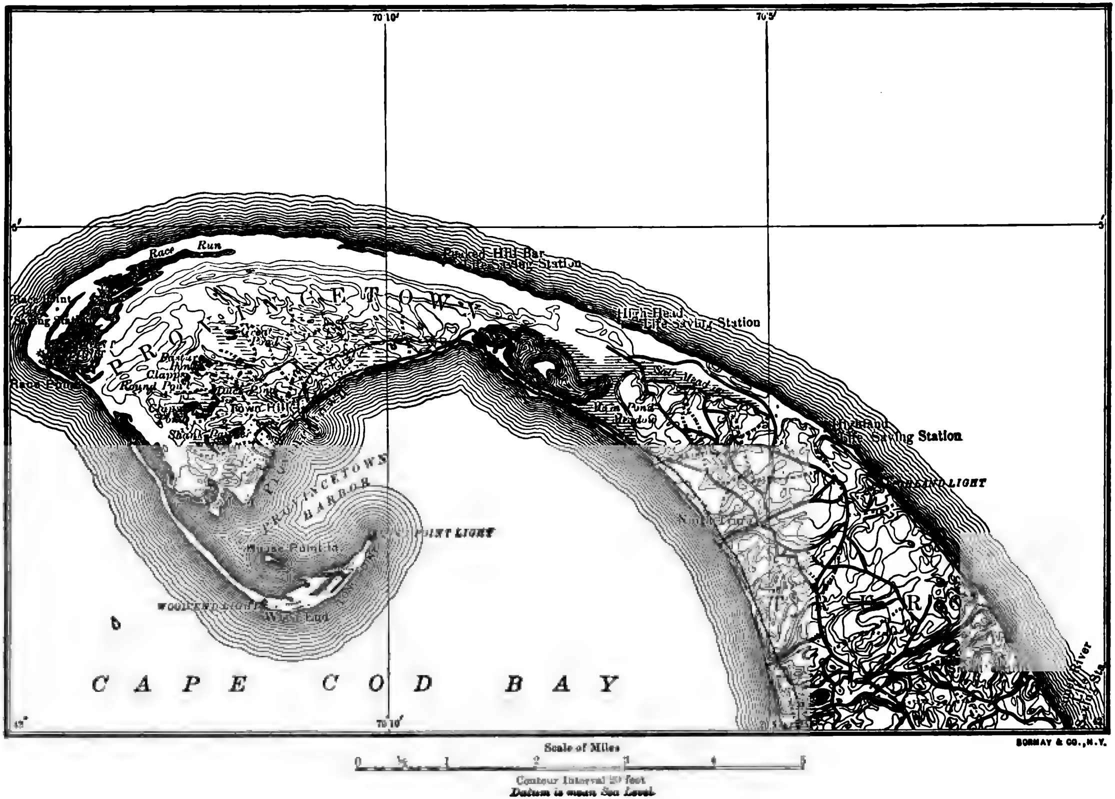

FIG. 375.—Cape Cod, Mass., showing Highland Light cliff (Fig. 367). The base of the cape is terminal moraine; the end, mainly sand dunes and sand bars, the sand having been supplied from the cliffs on the back shore. Long Point is a hook built of sand drifted along the coast. (Provincetown Sheet, U. S. Geological Survey Topographic Map.)

FIG. 376. — A view on the offshore bar of one of the Sea Islands.

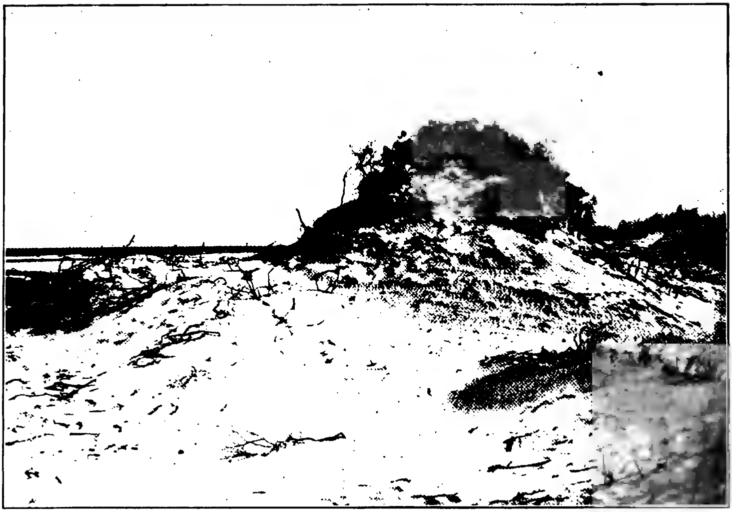

FIG. 377. — Sand dunes on the offshore bar of the New Jersey coast. The dune hill in the foreground is protected from removal by a cluster of bushes (bayberries) which have taken root there.

Fig. 378. — A salt marsh plain in an estuary at Cape Ann, Mass. View taken at mid-tide to show the channel-ways filled with water. During high tide the entire plain is submerged beneath the salt water.

Fig. 379. — A mangrove swamp on the Florida coast. Notice the tangle made by the roots of the mangrove, some of them descending from the limbs.

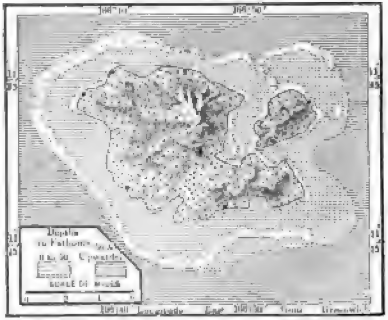

Fig. 381.—A fringing reef around Vanikoro Island in the Marshall Island group of the Pacific. If this mountain sinks slowly beneath the water, an atoll will be left.

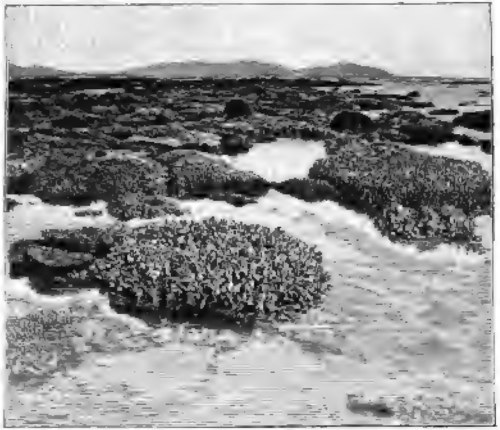

Fig. 380.—Corals on the Great Barrier Reef of Australia.

Fig. 382.—One of the Caroline Islands, an atoll in the Pacific.

built to exclude the sea, and the land drained, salt marshes make excellent farm land. Much of the fertile lowland of England, a large part of the Netherlands, and the beautiful Evangeline country of Nova Scotia are diked marsh land. In the United States little has been done to reclaim salt marsh, because we have had enough land without it. But the time cannot be far distant when the extensive salt marshes near New York and Boston will repay diking. Boston is partly built on salt marsh that has been changed to dry land by filling with earth removed from neighboring hills.

Summary. — *In protected bays and lagoons, sediment and the remains of salt-water plants build up salt-marsh plains. In places these have been reclaimed by dikes or by filling.*

154. Mangrove Swamps. — Mangrove trees grow in protected spots on the coasts of warm countries, such as the Philippines, Bermuda Islands, and southern Florida. The mangrove tree (Fig. 379) is firmly anchored by roots that descend from the branches, forming an almost impenetrable jungle, or mangrove swamp.

Summary. — *In warm countries the salt marsh is replaced by the almost impenetrable jungle of the mangrove swamp.*

155. Coral Reefs. — On some warm coasts animal life is so abundant that the shore is made entirely of animal remains. Of these animals, corals are the most important. Reef-building corals thrive only in depths less than 150 feet, where there is little sediment, little fresh water from the land, currents bringing abundant food, and a temperature never below 70°.

Coral is made by lowly animals, of which there are many species, varying in size from almost microscopic to individuals several inches in diameter. Some species live singly, but most unite in colonies, together forming a limy framework (as animals form their bones), which we call coral. Some corals are massive, bowlder-like domes, others, delicately branching, treelike forms. The individuals, or *polyps*, which form the coral, dwell in little cavities that dot its surface. The coral mass is alive on

the outside, dead on the inside, and the polyps build their coral homes on foundations laid by former generations.

The polyps can either withdraw into the cavities or extend their branching arms into the water in search of food. To one looking down upon a coral reef, through a box with a glass bottom, the sea floor seems like a garden, with flowers of all colors and many forms; and among the corals are myriads of other animals, some fixed in place, some moving freely about. The abundance and variety of life in such a place is marvelous.

Coral growth is most rapid on the outer side of a reef, where food is most abundant. This causes reefs to grow seaward, and their outward growth is increased by the action of the waves, which break off coral fragments and drag them out to sea. A reef may start close to shore, as a *fringing reef*, and advance so far that it becomes a *barrier reef*. Another way in which a fringing reef may be changed to a barrier reef is by a slow sinking of the land. If the coral grows upward as fast as the land sinks, it will form a reef farther and farther from the sinking land.

There are coral reefs on many coasts, the longest in the world being the Great Barrier Reef (Fig. 380), which for over 1000 miles skirts the northeastern coast of Australia at a distance of 20 to 50 miles. Behind it is a navigable lagoon of quiet, protected water, in which, however, a good pilot is necessary, because of the many coral shoals.

Uplift of the coast adds coral reefs to the land, in the form of terraces, like those in Cuba and other islands. Even in the interior of continents, fossil reefs are found in some of the limestone strata that were deposited in ancient oceans.

Waves and winds often heap the coral fragments above sea level, forming land, as in the Bermuda Islands. The Bermudas, whose base beneath the sea is a volcanic cone, are surrounded by a fringe of coral reefs. Fragments, broken from the reefs by the waves, are ground on the beaches to coral and shell sand, then drifted inland by the winds, forming sand dunes. These are

quickly cemented into a soft rock by the deposit of carbonate of lime around the grains. The Bahamas, and many other coral islands, are made in the same manner. The soil of such dunes is far better than the soil of ordinary sand dunes.

Summary. — *In warm, clear water, where there is an abundance of food for fixed animals, corals thrive, building limy skeletons, out of which reefs are made. Fringing reefs are made along the coast, and these may change to barrier reefs either by outward growth or by sinking of the land. The wind often forms dunes of the coral sand drifted from the beaches, thus making land in the sea.*

156. Atolls. — Ring-shaped islands in the open ocean, made of coral fragments, are called *atolls* (Fig. 382). A channel into the interior lagoon is kept open by the incoming and outgoing tides. Atolls are especially common in the South Pacific, and are in some cases several miles in diameter, though rarely rising more than 12 to 15 feet above sea level. They are so low that during hurricanes they are sometimes inundated by the sea. Like the Bermudas, the part above water is made of coral and shell fragments that the waves have thrown on the beach and the wind drifted into low hills.

Few animals have reached these remote islands; but there are numerous plants, including the cocoanut palm. Many atolls are inhabited by man.

Atolls are built on the peaks of extinct volcanoes that rise from the sea bottom. Sometimes they seem to have been built on submerged peaks, the ring shape being due to the faster growth on the outside of the reef, while within the lagoon much of the lime of the coral is removed by solution. In other cases the atolls appear to be due to a slow subsidence of volcanic cones (Fig. 385). According to this explanation there was first a volcanic island surrounded by a fringing reef (Fig. 381); by slow sinking this changed to a barrier reef; finally, when the cone had entirely disappeared, there was a ring-shaped atoll where the cone formerly rose. The sinking of the cone could have been no faster than the upward growth of the reef.

Summary. — *Low, ring-shaped coral islands in the open ocean are called atolls. They are built on volcanic cones. In some cases at least, they are caused by a subsidence of the cone at about the same rate as the upward growth of a fringing reef.*

157. Lake Shores. — Most that has been said about sea-coasts applies quite fully to lakes; and illustrations of most shore-line phenomena are found along lake shores. There are headlands, wave-cut cliffs, beaches, bars, sand dunes, islands, promontories, and harbors. There are also elevated and drowned coasts. In fact, from the form alone it is quite impossible to distinguish lake from ocean shores. Figures 358 and 370 are from lake shores.

It is true that tides are absent in all but the largest lakes, and even there are almost unnoticeable; and, because the waves are less violent, the cliffs are usually smaller, resembling those of bays rather than the open ocean; but in great lakes there are some high cliffs.

The effects of life are, however, quite unlike in the two cases. Although swamps are formed in the lagoons and bays of lakes, the plants are very different from those of the salt marsh; and the absence of tide makes the difference between lake and sea-shore swamps even more marked. In lakes there are no corals, and, consequently, no coral reefs.

Summary. — *Lake and sea-coasts are so alike that, from the form alone, they could not be distinguished. The chief differences are the smaller cliffs, the absence of tides, and the effects of life.*

158. Abandoned Shore Lines. — In many places where lakes have disappeared, cliffs and beaches are now found on the land. For example, very perfect beaches, bars, spits, and cliffs are found near Great Salt Lake, marking the shore line of ancient Lake Bonneville (Fig. 301). Similar shore lines mark the level reached by the glacial lakes in the valleys of the Red River of the North (Fig. 130) and the Great Lakes (p. 150). Such beaches are seen at or near Duluth, Chicago, Cleveland, Rochester, Syracuse, and many other points. They are so much like ocean shore lines,

Fig. 383. — A wave-cut cliff on the French coast. In cutting back the land, the waves have left a "stack" island. Another will be formed when the roof of the wave-cut cave falls.

Fig. 384. — Elevated wave-cut cliff on the west coast of southern Scotland. Just beyond this cliff is a sea cave with fields extending up to it.

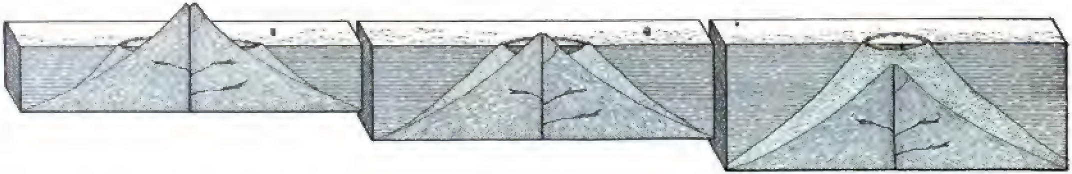

FIG. 385.—Diagram to illustrate the way in which an atoll may be formed by the slow sinking of a volcanic cone.

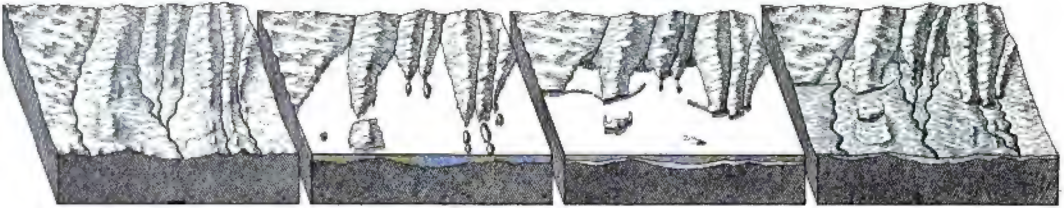

FIG. 386.—To illustrate the changes in a coast line of hard rock, like that of New England. First figure (left) shows a hilly land; second, the same land partly drowned; third, same after cliffs have been cut, bars built, and deltas formed; fourth (right), same elevated. Describe the changes illustrated in these four pictures.

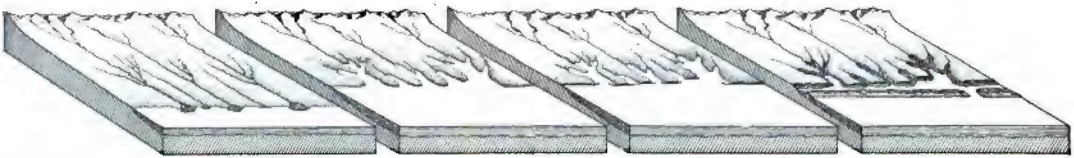

FIG. 387.—To illustrate the life history of a low coast of weak rock, like that south of New York. First figure (left), a sandy coastal plain with streams in shallow valleys; second, the same lowered; third, the first stage of wave work, forming cliffs and short bars (see Fig. 372); fourth, offshore bars have been formed with salt marshes behind, partly filling them. This is the stage shown in Fig. 372. In a further stage the offshore bar would be pushed back and the waves once more allowed to attack the mainland.

Fig. 388. — The drowned coast of a part of southern New England. Notice the small bays partly or completely shut in by bars. (A part of the United States Geological Survey, New London, Conn., Sheet.)

Fig. 389.—The drowned coast of a part of Maine. (United States Geological Survey, Boothbay, Maine, Sheet.)

that for a while they were supposed to have been caused by a sinking of the land, admitting the sea into these valleys.

Elevated sea beaches are found from southern New England to Baffin Land. Near Boston these beaches are from 40 to 60 feet above sea level; in Labrador several hundred feet. There are also elevated beaches in Norway, Scotland, and other parts of northwestern Europe. Here the country back of the elevated shore lines is irregular, rocky, and not well suited to farming; but between the elevated beaches and the present shore is a narrow plain which is good farm land and well settled. It is an elevated sea bottom, from which the waves have partly removed the islands and promontories, and over which sediment has been strewn (Fig. 386). Proof of former wave work at these higher levels is furnished by elevated beaches, marine fossils, islands partly cut away, and cliffs (Fig. 384) with sea caves and chasms.

Summary. — *Shore lines, closely resembling marine shore lines, mark the sites of extinct lakes; and elevated sea beaches are found in northeastern America and northwestern Europe.*

159. Life History of a Coast Line. — Elevations and depressions of the land are so frequent that, before the waves have carried their work very far, some change in level brings new regions within their reach. If a coast were allowed to pass through its life history uninterrupted, the changes would depend on the nature of the rock, the form of the coast, and the force and direction of waves and currents.

We will start with a rocky, irregular, exposed coast, like that of New England, — a typical *young coast line* (Fig. 386). Slowly the headlands are cut back (Figs. 362, 383), some of the materials being moved offshore, some driven along the coast. Of the materials driven alongshore, bars are made, tying islands to the mainland (Fig. 369) and closing the bays (Fig. 370, 373). Sediment slowly fills the bays, transforming them to salt marshes (Fig. 378), then to dry-land plains. This straightened coast is a *mature coast line*. As the waves continue to cut back the headlands, the beaches and bars are also pushed back, and thus the entire coast line retreats.

If the rock is weak, less time is required for this life history; and if at the beginning the coast is not very irregular, less time is required to straighten it. On coasts of loose sand and clay, with gently sloping bottom, cliffs are first cut, then offshore bars are thrown up (Figs. 371, 372, 387). As in the case of other straightened coasts, the waves then gradually push the barrier beaches back toward the land. Coral coasts have a different life history, for they depend on the growth of animals.

Summary. — *Young coasts are irregular; as they advance toward maturity headlands are cut back, bay mouths are closed, and irregularities are filled; then both headlands and beaches are slowly moved backward as the land is consumed. This life history requires a longer time in hard than in soft rock. On gently sloping coasts of soft rock, one of the earliest stages is the building of offshore bars.*

160. Islands and Promontories. — Perhaps the greatest number of islands and promontories are due to sinking of the land (Figs. 349, 352–354, 388, 389), as illustrated by those of northeastern and northwestern America, northwestern Europe, southern South America, and the Grecian coast.

Other islands and promontories are built by mountain growth (pp. 98, 207). Alaska, Lower California, the West Indies, the large peninsulas and islands of the Mediterranean, Madagascar, New Zealand, the East Indies, the Malay Peninsula, the Philippines, the Japanese islands, Korea, and many chains of oceanic islands are of this origin. Many islands in the open ocean are volcanoes (pp. 124, 175); for example, the Azores, Canaries, Madeiras, and Hawaiian Islands.

Atolls and many coral reefs are islands built by animal life, aided by waves and wind (p. 218). These are illustrated by the Bahamas, Bermudas, and the islands off southern Florida, including Key West. Some coral reefs are attached to the land, forming promontories. The formation of barrier beaches (p. 214) is another cause for islands and promontories (Figs. 368, 375), as illustrated along the coast of the United States. Deltas are often promontories; and along their shores are many small islands and promontories that the waves have thrown up (Fig. 105).

Another cause for islands and promontories is the faster work of the waves in removing weak strata (p. 211). Small islands thus cut from the mainland are often called *stacks* (Figs. 366, 383).

The deposit of bars of sand or pebbles in the protected water behind islands often ties them to the land, changing them to promontories (Fig. 369). The rock of Gibraltar is thus tied to the mainland of Spain (Fig. 390), and a part of the bar is neutral ground between English and Spanish territory. Sometimes an island is tied by two bars, one from each end, inclosing a lagoon between them.

FIG. 390. — The rock of Gibraltar, from the Spanish coast, showing the bar that joins it to the mainland.

Promontories and islands form irregularities of the coast line, and are usually the boundaries of bays, or other indentations. Therefore, the causes for islands and promontories also explain most of these indentations.

Summary. — *The majority of islands and promontories are caused by sinking of the land. Other causes are mountain growth, volcanic action, coral reef building, the formation of barrier beaches, the growth of deltas, and the irregular cutting by waves. Bars deposited behind islands often change them to promontories. These causes also account for most of the bays and other indentations.*

161. Harbors. — No feature of the seacoast is more important than the harbors, or small indentations of the coast, deep enough for vessels to enter, and protected enough for them to remain safe from wind and wave. By far the greater number of harbors are caused by sinking of the land, admitting the water into the valleys (Figs. 350, 388, 389); but there are many other causes for harbors.

Some, like that of New Orleans, are on large rivers where there has been little or no sinking; others, like that of Naples, occupy bays formed by mountain uplift; and still others, like that of Callao, are merely part of a straight coast where an island serves to cut off the winds and waves. What is the cause for Galveston harbor (p. 214)? There are others of similar origin. The lagoon of an atoll (Fig. 382), and a volcanic crater breached by the sea (Fig. 234), may also form harbors. Among other causes is the work of man; for he has made many harbors, either by dredging shallow tidal rivers, as at Glasgow, or by building breakwaters on harborless coasts.

For a harbor to be useful at the present day, and to become the site of a great city, it must be deep enough to admit large vessels. It was partly because of the shallowness of its harbor that Salem was outstripped by its neighbor Boston; but, of late, even Boston harbor has needed deepening and improvement to admit large modern ships.

To become the site of a great city, a harbor should also have a large area of productive country tributary to it. Baltimore, Philadelphia, New York, and Boston harbors are open to shipment not only from the country round about, but also from the great interior; and New York owes its superiority over the others largely to the fact that it has connection with the interior by water as well as by rail. On the other hand, Castine, Me., has a better harbor than even New York; but it is not connected with an extensive productive country, and consequently has not developed.

Harbors, like many other coast forms, are temporary affairs. If the coast remains at one level, and man does not interfere, bars will grow across harbor mouths and they will be slowly filled with sediment. Both of these processes are in operation, and it is necessary to expend large sums of money to remove the deposits. This is especially true on sandy coasts, where the waves and currents find much loose material to drift about. For this reason

the entrance to New York harbor is through a long, tortuous channel dredged out amid shoals of sand drifted from the sandy shores of Long Island and New Jersey.

Summary. — *A harbor is an indentation of the coast, deep enough for vessels to enter and yet be protected from winds and waves. There are numerous causes for harbors, of which sinking of the land is most important; man also makes harbors by dredging or by building breakwaters. To be the site of a great city, a harbor must be deep enough for large vessels and have an extensive area of productive country tributary to it. Waves and currents are tending to seal up and fill harbors.*

Topical Outline, Questions, and Suggestions.

Topical Outline. — 142. **Importance of Shore Lines.** — Centers of industry; shipping; charts; Coast Survey; harbor improvements; dangers of approach; lighthouses; light-ships; fog-horns; pilots; buoys; life-saving stations; summer resorts.

143. **The Seacoast is ever changing.** — Wave work, — instances; deposit, — instance; effect of elevation; of depression; the ever changing coast.

144. **Elevated Sea-bottom Coasts.** — Nature of coast; illustrations; unhealthfulness; agriculture; harbors; sinking of coast; sand bars.

145. **Straight Mountainous Coasts.** — Effect of uplift; western America, — straight coast, mountains, narrow plain, sea-bottom slopes; recent uplift; settlement, — few harbors, limited resources, mountain barrier.

146. **Irregular Mountainous Coasts.** — Cause of islands; of peninsulas; sinking of crust between ranges; Mediterranean, — cause, entrance, irregular coast; other large seas; small irregularities; sinking of coast; settlement; communication by land; navigation; western Italy.

147. **Coasts of Drowned Lands.** — (*a*) Resulting irregularity: bays and harbors; instances; drowned rivers; shoals and banks; islands; peninsulas. (*b*) Fiord coasts: origin of fiords; instances; settlement. (*c*) Regions of soft rock: effect on coast form; settlement. (*d*) Importance of irregular coasts: harbors; length of coast line; fishing and navigation; interior waterways; instances. (*e*) Islands: isolation; Newfoundland; Great Britain.

148. **Wave and Tide Work.** — Movement of fragments (*a*) offshore, (*b*) alongshore; result; reasons for irregular coasts; straightening coast.

149. **Sea Cliffs.** — Zone of wave work; work of breakers; steepness of cliffs, hard rock, soft rock, height; chasms; sea caves; limit to wave work; offshore platform; cutting back of land; dangers to navigation.

150. **Beaches, Hooks, Bars, etc.** — Disposition of fragments; quicksands; pocket beaches; grinding of pebbles; bars across bays; bars supplied from sea cliffs; hooks; spits; cusps.

151. **Offshore Bars.** — Instances; lagoons; gaps in bars; closing of gaps; cause of offshore bars; effect of wind; destruction of bars; occupants of bars; cities on bars; shoals.

152. **Sand Dunes of the Seacoast.** — Location; form; effect of removal of forest; instances; encroachment; uselessness; Netherlands.

153. **Salt Marshes.** — Location; aid of plants; channels on marsh; change to dry land; value; diked land; illustrations; United States.

154. **Mangrove Swamps.** — Location; jungle.

155. **Coral Reefs.** — Favoring conditions; differences among corals; polyps; abundant life in a coral reef; growth of reef; fringing reef; barrier reef; two causes for barrier reefs; Great Barrier Reef; elevated reefs; making of land; Bermudas.

156. **Atolls.** — Form; lagoon; size; elevation; cause of elevation; plants, animals, and man; two explanations.

157. **Lake Shores.** — Resemblance to ocean shores; phenomena in common; absence of tides; smaller cliffs; effects of life.

158. **Abandoned Shore Lines.** — Lake shores; instances; resemblance to ocean shore lines; elevated sea shores; instances; characteristics.

159. **Life History of a Coast Line.** — Controlling conditions; young coast; changes in young coast; mature coast; consuming of land; effect of weak rock; offshore bars.

160. **Islands and Promontories.** — Sinking of coast; mountain growth; volcanoes; coral reefs; barrier beaches; deltas; instances of each; wave work; stacks; tied islands; causes of indentations.

161. **Harbors.** — (*a*) Definition. (*b*) Causes: sinking of land; rivers; mountain uplift; islands; lagoons behind barrier beaches; atoll lagoons; crater harbors; work of man. (*c*) Sites of great cities: depth; tributary country; illustrations. (*d*) Sealing up of harbors: bars; filling.

QUESTIONS. — 142. For what is the coast most important? What does the government do to fit it better for commerce? To warn sailors of danger? To protect them? Why is the coast a summer resort?

143. In what different ways is the coast changing?

144. What conditions are unfavorable to the development of elevated sea-bottom coasts? Why are the harbors so poor?

145. What are the results of the rising of long chains of mountains? What is the condition on the coast of western South America? Why are such conditions unfavorable to dense population?

146. How does mountain growth cause irregular coasts? What are the conditions in the Mediterranean? Give other instances of irregular

coasts. What is the condition in Greece? Why are such coasts favorable to navigation? Why unfavorable to dense settlement?

147. What results are produced by entrance of the sea into valleys? Give illustrations. What are the results of complete or partial submergence of hills? How do the nature of the rock and the valley form influence the coast outline? What effect has this on settlement? Why are moderately low, irregular coasts favorable to settlement? What effect has sinking of the land on island people? Give illustrations.

148. What work are the waves and currents doing? What effect does this have on irregular coasts? Why are not all coasts regular?

149. How are sea cliffs formed? How do cliffs in hard and soft rocks differ? What effect has variation in strata? What are the results of cutting cliffs back? What effect has this on navigation?

150. What becomes of the rock fragments drifted along the shore? How do the materials vary? What forms are assumed by the beaches and bars thus built?

151. Describe the bars along the Texas coast. How are they formed? Of what importance are barrier beaches?

152. What are the characteristics of sand dunes? What damage do sand dunes accomplish? What is the condition in the Netherlands?

153. Where are salt marshes formed? How? What is the result? Of what importance are salt marshes?

154. What are mangrove swamps? Where are they found?

155. Under what conditions do corals thrive? How is the coral made? How do the polyps live? How do the reefs grow? In what two ways may fringing reefs be made? Describe the Great Barrier Reef. What is the origin of the Bermudas and Bahamas?

156. What are the characteristics of atolls? Where are they found? How are they caused?

157. Compare and contrast lake and sea shores.

158. Give instances of abandoned lake-shore lines. Of elevated seashore lines. What is their nature?

159. What causes are there for variation in the life history of a coast line? State the life history of a hard rock, irregular coast. What differences are there where the rock is weak?

160. State the different causes for islands and promontories. Give instances wherever possible. How may an island be changed to a promontory? What are the causes of indentations?

161. What is the cause for most harbors? State other causes for harbors. What two factors are of importance in determining the growth of cities about harbors? Give two instances. Why must money be spent to improve harbors?

SUGGESTIONS. — (1) Take some angular fragments of a soft rock, or brick, and shake them for a few moments in a fruit jar containing water. What causes the water to become muddy? Find out how marbles are rounded. (2) In a shallow pan, mold an irregular land of clay. Carefully pour in water until the land is partly drowned. Study the land forms produced. Blow on the water surface, causing the waves to reach the coast diagonally. Are any bars formed? Any other coast-line features? Study and describe them. Now draw off some of the water to leave the shore line elevated. Describe the new coast line. How does it differ from the former? Cause waves to attack it, and describe the result. By using care, and by making the land of materials varying in hardness, much concerning shore-line phenomena may be simply and easily illustrated. (3) If the school is near the seashore or the shore of a lake, at least one excursion should be made to study shore phenomena. Are there beaches? Where does the material come from? Are there cliffs? What is happening there? Have any portions been recently removed by the waves? Do the bowlders or pebbles show signs of rounding? What is the cause? Where does the finer ground-up material go? Are there any mud flats? What is the source of the material? Ask some fisherman what material covers the bottom offshore. Are there salt marshes? What are their characteristics? Are tidal currents performing any work? (4) If the school is on a sea or lake port, the harbor should be studied; its form; depth (making use of a Coast Survey map); cause; nature of bottom; improvements made; others needed; lighthouses; other guides and aids to entrance; source of principal materials received for shipment; of principal imports; places to which these are distributed; reasons for importance of port. If not on a harbor, the nearest large port should be studied in a similar way by means of the Coast Survey or Lake Survey charts (see Appendix J).

Reference Books. — SHALER, *Sea and Land*, Scribner's Sons, New York, 1894, $2.50; TARR, Chapter X, *Physical Geography of New York State*, Macmillan Co., New York, 1902, $3.50; SHALER, *Beaches and Tidal Marshes of the Atlantic Coast, National Geographic Monographs*, American Book Co., New York, 1895, $2.50; GILBERT, *Features of Lake Shores*, 5th Annual U. S. Geological Survey, p. 75; SHALER, *Salt Marshes*, 6th Annual U. S. Geological Survey, p. 359; SHALER, *Harbors*, 13th Annual U. S. Geological Survey, p. 99; DARWIN, *Structure and Distribution of Coral Reefs*, Appleton & Co., New York, 1889, $2.00; DANA, *Corals and Coral Islands*, Dodd, Mead & Co., New York, 1895, $5.00.

CHAPTER XII.

THE ATMOSPHERE.

162. Composition of the Air. — (A) *Oxygen, Nitrogen, and Carbon Dioxide.* — Until recently air was believed to be a mixture of two gases, *oxygen* (about 21 per cent) and *nitrogen* (about 79 per cent).[1] Oxygen is of vital importance to animals, for all breathe it; but nitrogen, though used by some plants, is of far less importance. It, however, increases the bulk of the air and dilutes the oxygen. Man probably could not live in an atmosphere of pure oxygen, for it would cause too rapid changes in the tissues of the body.

About 0.04 per cent of the air is carbon dioxide (often called carbonic acid gas), which, in spite of its small quantity, is very important. It is composed of one part of carbon and two of oxygen, and plants have the power of separating them, building the carbon into their tissues.

In the bodies of animals, on the other hand, oxygen unites with carbon by a process of slow combustion, and with each breath carbon dioxide is returned to the air. Fire is a more rapid form of combustion, oxygen combining with the carbon of the wood, coal, oil, etc., and forming carbon dioxide. All forms of combustion, whether rapid or slow, produce heat. In such rapid combustion as fire, sufficient heat is produced to do much work, — for example, the formation of steam, whose energy may be used to run locomotives or

[1] In 1895 a new element, *argon*, was discovered in the atmosphere, and since then several other inert elements have been found in it. They resemble nitrogen so closely that, although they are taken with every breath, they were never before detected.

machinery. By slow combustion the necessary heat is produced to form the energy which animals need for life.

Summary. — *The atmosphere is a mixture of gases. Argon and nitrogen are quite inert; carbon dioxide, which exists in very small quantities, is of vital importance to plants; oxygen is breathed by all animals, in which it produces slow combustion, giving the necessary heat for life. It also causes rapid combustion in fire.*

(B) *Water Vapor.* — Vapor rises from all damp surfaces and water bodies; that is, liquid water is *evaporating* or changing to an invisible gas. This is the reason why wet clothes become dry when hung on a line, and sidewalks, after a rain. The amount of vapor water varies from place to place, some regions having very dry air, others damp or humid air. Even in the same place the amount of vapor differs from time to time, some days being humid, others dry. When the air is dry, evaporation is rapid and the sky clear; but when there is much vapor, there may be clouds and rain. The condensation of this water vapor gives rise to dew, frost, fog, clouds, rain, snow, and hail.

Summary. — *Invisible water vapor, which rises from water bodies and damp surfaces, is also mixed with the air, in varying amounts.*

(C) *Dust Particles.* — Solid particles that float in the air are called dust. Some of this is dust whirled up from the ground by winds; some are bits of carbon from smoke, or pollen of plants, or microbes. Dust particles accumulate around cities, causing a dull, hazy atmosphere; but during long periods of drought, or when forest fires are burning, the air even in the country becomes hazy with dust. Rain washes dust from the air, so that it is usually clearer after a rain storm. Over the ocean, and on high mountains, the air is quite free from dust particles.

Dust is important in furnishing solid particles around which vapor condenses to form fog and rain. The microbes are drifted about by the winds, thus helping to spread disease.

Summary. — *Particles of dust, smoke, microbes, and other solids often cause the air to be hazy, especially near cities.*

163. Effect of Gravity. — Although light and invisible, air has perceptible weight. One particle, drawn down by gravity, presses on those below it, as stones in a pile press on those beneath. Since the air extends to a height of two hundred miles or more, this great column has a weight that can be measured. At sea level, its average weight is 15 pounds to every square inch of surface. This is equal to a column of about 30 feet of water, or 30 inches of mercury.

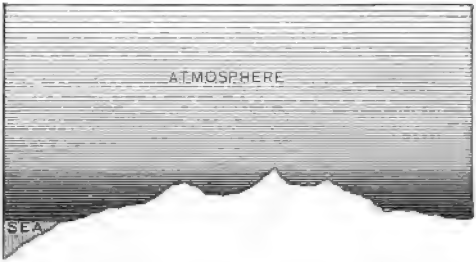

FIG. 391. — To illustrate the decrease in density of the atmosphere from sea level to higher regions.

Since there are many square inches on the surface of a human body, it is evident that each of us bears a great weight of air; but as the pressure is equal, both inside and out, we do not notice it (p. 181). If this pressure were suddenly removed from the outside, the expansion of the air within our bodies would burst many of the tissues.

Pressure pushes the molecules of gases closer together; and, therefore, the air is denser near the earth than higher up (Fig. 391). As a result of this, fully two thirds of the atmosphere is within six miles of sea level; and the air is about half as dense at the top of a high mountain, like Mt. St. Elias, as at its base. The air on mountain tops is so thin, or *rarefied*, that it is difficult to breathe oxygen enough for the needs of the body. Some men and animals have become accustomed to this rarefied air and are able to live in high altitudes; but a traveler from lower levels finds his breathing greatly quickened by the effort to get enough oxygen, and not uncommonly he becomes quite exhausted.

Air is so extremely elastic that even slight differences in temperature change its density or weight. For example, the air filling a room $10 \times 20 \times 20$ feet weighs 301 pounds at 60°; but

when the temperature is raised to 80°, the air is so expanded that there are only 291 pounds in the room.

The pull of gravity is greater on heavy than on light air, and these differences in weight start movements of the air, causing winds (p. 255).

Summary. — *Air has weight, at sea level about fifteen pounds to the square inch. It is compressed, or more dense, at the bottom; and lighter, or more rarefied, higher up. It is very elastic, varying in density with temperature, and being easily set in motion.*

164. Light.[1] — A form of energy, commonly called light and heat, is emitted by bodies having a high temperature; for example, burning coal, red-hot iron, and the white-hot sun. This energy travels at great speed, crossing the 93,000,000 miles which separates earth and sun in about 8 minutes.

The sunlight which comes to us is made of a series of waves, differing in length and color, whose union forms white light. If a beam of sunlight is allowed to pass through a three-cornered glass prism these waves are turned, each at a slightly different angle. The beam enters as white light, but comes out with the color waves separated, among which violet, indigo, blue, green, yellow, orange, and red may be recognized. This bending of light rays is called *refraction;* the colors are called the *colors of the spectrum*, or of the rainbow.

Some of the rays that reach a body pass away from it, or are *reflected.* This is especially true of smooth surfaces, like water, or the glass of a mirror; but it is true even of irregular surfaces, like the ground. It is reflected sunlight that makes the moon and planets appear light; and the earth would have the same appearance if seen from them.

Refraction and reflection cause many changes in light as it passes through the atmosphere. *Mirage* is caused by reflection

[1] A thorough study of the nature and behavior of light belongs to physics; but the student of physical geography should understand the main reasons for the color phenomena of the atmosphere.

when layers of air have different temperatures and, consequently, different densities. It is especially perfect in deserts and on the sea, commonly showing objects inverted — a vessel with the masts downward, for instance. In deserts mirage causes an appearance of water which is often very deceptive.

Rainbows are caused by refraction of light in its passage through raindrops, and reflection of the spectrum colors thus produced. The *halos* around sun and moon are due to similar changes in the light rays, in their passage through the ice crystals of thin, fleecy clouds high in the air.

The colors of leaves, flowers, and other objects are due to reflection. When light reaches some objects, for example white paper, all the waves are reflected and the paper appears white. Other objects, like black cloth, reflect very little light, the rays being absorbed. Still other objects absorb some of the waves and reflect others, thus giving color. A red flower, for instance, reflects an excess of red waves; and green leaves, green waves.

Diffraction, or *selective scattering,* is an important cause for color effect in the sky. Dust in the air interferes with the passage of light waves, as small pebbles in shallow water interfere with water waves. By this interference, some of the waves that make the white light are turned aside, or *scattered.* The waves having the shortest length, or those on the violet end of the spectrum, are most easily turned aside; that is, they are selected for scattering.

The blue color of the sky is due to the selective scattering of the short blue waves. When there is much dust in the air, the longer red and yellow rays are scattered, giving red and yellow colors to the sky. These colors are especially common at sunrise and sunset, when the rays pass for a long distance through the lower dust-filled layers of the air (Fig. 392). The varied cloud colors of sunrise and sunset are the result of reflection of colors caused by refraction and diffraction.

Summary. — *White light is made by the union of a number of waves of different length, which, when separated by refraction, give the colors of the spectrum. These colors may be reflected, as in colored objects, rainbows, halos, and clouds at sunset. The scattering,*

or diffraction, of waves by the interference of dust gives the blue color to the sky and the reds and yellows of sunrise and sunset.

165. Heat. — (A) *Radiant Energy.* — On approaching a hot stove one feels its warmth, even at a distance of several feet. Waves of heat from the stove have passed that distance through the air. If the stove is very hot, the cover may be red; then the waves from it produce not only heat, but the sensation of light on the eye. This form of energy, which we call heat and light, is known as *radiant energy*, and the process of emitting it is called *radiation*. The greatest well-known center of radiant energy is the sun; but doubtless some of the stars are still larger and hotter, though so far away that they do not influence us.

Radiation causes a loss of heat, and by it bodies grow cooler; thus, in a few hours, a stove with the fire out will radiate all its heat and become cold. The sun is also losing heat, radiating it outward in all directions; but millions of years would be required for so large and hot a body as the sun to grow cold. A very small proportion of the heat radiated from the sun is intercepted by the earth (Fig. 15), where it causes many important effects.

Summary. — *Radiant energy, heat and light, which is emitted from hot bodies, is being radiated in all directions from the sun, which is, therefore, slowly growing cooler.*

(B) *Passage of Radiant Energy.* — Certain substances, like glass and the gases of the air, allow light to pass so freely that they are said to be *transparent*. They also allow heat to pass freely, or are *diathermanous*. For this reason, notwithstanding the thickness of the atmosphere, the sun's rays at midday reach the earth's surface with little change.

Dust particles interfere with the passage of light rays, as we have seen; and, in much the same way, they interfere with the passage of heat. This is clearly proved by the difference in brightness and warmth of the sun at midday and

late in the afternoon; for we may often actually look at the setting sun. At that time many of the rays are intercepted in their passage through the great thickness of dust-laden air near the surface (Fig. 392).

Summary. — *Air and other substances transparent to light allow heat to freely pass, or are diathermanous. The interference of dust greatly lessens the sun's power when it is low in the heavens.*

(C) *Radiation from the Earth.* — Bodies that are warmer than their surroundings emit waves of radiant energy. The earth itself is radiating into space the heat that comes to it from the sun; if this were not so, it would grow warmer and warmer. During the day more heat comes than can be radiated; but at night, when the sun's rays are cut off, radiation cools the ground. In summer, when the days are longer than the nights, the ground grows steadily warmer; but in winter, when the days are short and the sun low in the heavens, radiation is so far in excess of the supply of heat that the ground becomes cold.

Some bodies are much better radiators than others. Rocks and earth radiate heat better than water, and hence cool more quickly. This is one reason why, in winter, the land becomes colder than the water. On cold nights those objects that radiate their heat most quickly have most frost. Perhaps you can observe this difference early some frosty morning.

Summary. — *The earth is always radiating heat, and this is why it becomes cool or cold at night and in winter. Some objects, like water, are poorer radiators than others, like the ground.*

(D) *Reflection and Absorption.* — Bodies that reflect light also reflect heat. Water, for example, reflects a large percentage of the rays that reach its surface, and this is why one becomes sun-burned so easily on water. Quarries and city streets are warmer than the open country, partly because the sun's rays are reflected from their walls.

236.1 Some bodies reflect little, the sun's rays being used mainly in warming them. Such bodies are said to *absorb* heat. This is especially true of black objects, while white objects reflect; therefore white clothing is cooler than black. This can be readily proved in winter by placing two pieces of cloth, one black, the other white, on a bank of snow in the sunlight. The black cloth soon sinks into the snow because the sun warms it, while the white cloth remains at the surface.

236.3 **Summary.** — *Some bodies, such as water and white objects, reflect much heat; others, such as black objects, absorb heat and, therefore,* ~~*warm*~~ heat *more rapidly.*

(E) *Conduction.* — With a fire inside of it a stove becomes warm; and an iron placed on the stove is also heated. In this case heat from the fire is transmitted, or *conducted*, through the stove. In the same way, some of the sun's heat is conducted below the surface of the water or ground, and 236 some of it into the air which rests on these; but water, air, and ground are not such good conductors as iron. The ground is so poor a conductor that, at a depth of from ten to twenty feet, there is practically no difference in temperature from summer to winter.

Summary. — *Heat is transmitted, or conducted, into the water and ground, and from these into the air; but air, water, and ground are all poor conductors.*

(F) *Convection.* — The lower layers of water in a kettle on a stove are warmed by conduction. Warm water is lighter than cooler water, and, since gravity tends to draw the heavy water to the bottom, these warm lower layers cannot stay there. They are, therefore, crowded up by the settling of the cooler layers from above. This is convection, and, if the water continues to warm, boiling finally takes place.

Similar convection occurs in air warmed by a lamp. As fast as it is warmed near the lamp it grows lighter and is pushed up by heavier surrounding air. The movement

of heavier air to crowd up warm air is what causes the draft in a fire; and the crowding upward of the warm air is what causes it to go up the chimney.

Heat from the sun is the cause for very extensive convection of the air in all parts of the earth. Warmed in one place, usually by conduction of heat from the ground or water, the warm light air is pushed away by heavier air drawn down by gravity. This is the cause of winds (p. 255).

Summary. — *Heat makes both water and air lighter; and gravity, by drawing down heavier air, causes a rising, or convection, of the warmer lower layers. Winds are thus caused.*

166. Warming of Land, Water, and Air. — (A) *The Lands.* — The lands are warmed by absorption during the day, and some of the heat is conducted into the ground, warming the upper few feet into which the roots of plants reach. The ground nowhere becomes excessively warm, because much of the heat is lost by reflection, by radiation, and by conduction into the air. Everywhere the ground warms during a hot, sunny day, and cools by radiation at night.

In the tropical zone the ground does not become very cool at night, because radiation is unable to remove all the heat that comes during the long, hot days. A similar condition exists during summer in the temperate zones; but, in winter, radiation during the long nights so chills the ground that it freezes. In the frigid zones, radiation during the long winter causes the ground to freeze to depths of hundreds of feet, and the short, cool summer supplies only heat enough to melt the upper two or three feet.

There are other differences in the warming of the lands. For example, dark-colored surfaces warm more quickly than light, and bare earth more quickly than that covered by vegetation. There are also differences according to exposure; for instance, between shady north slopes and sunny south slopes, and between hilltops and valleys, whose sides reflect heat into the valley and also interfere with winds and with radiation.

Summary. — *The lands are warmed by absorption and cooled by reflection, conduction, and radiation. The effect of sun's heat varies in different zones; also according to the color of the surface, the cover of vegetation, and the exposure.*

(B) *The Waters.* — It is a well-known fact that water warms less quickly than land. There are several reasons for this. (1) Water reflects heat more readily than land, and, consequently, there is less heat to warm it. (2) When one part is warmed more than another, it is set in motion, so that there is a tendency for the heat to be distributed. (3) Water is so transparent that, unlike ground, some of the rays pass into it, warming layers below the surface. Sunlight penetrates, though dimly, to depths of several hundred feet. (4) Twice as much heat is required to raise the temperature of a pound of water one degree as of an equal quantity of rock. Some of the heat is expended in evaporating the water, and this is called "latent heat," or *heat of vaporization.*

It is for these reasons that even a small body of water warms more slowly during the day, and during summer, than the neighboring land (p. 165). At night-time and in winter, on the other hand, because it is a very poor radiator, water cools more slowly than land. Therefore, from day to night, and from summer to winter, there is slight range of temperature in large water bodies, and the climate over them is far less extreme than over land. A climate with such slight changes of temperature is called *equable.*

Summary. — *Water warms more slowly than land because it reflects more heat, is movable, is transparent, and some of its heat is expended in evaporation. It cools more slowly because it is a poorer radiator. Therefore near large water bodies the climate is equable.*

(C) *The Air.* — The air is not perfectly diathermanous. Therefore, some of the sun's rays, and some of the heat rays radiated from the earth, are intercepted in their passage through the atmosphere. Dust is especially effective in

intercepting heat waves (p. 234). A still more important cause for the warming of air is conduction from the ground to the lower layers, which, being lighter, are then forced to rise by convection. In the same way a stove warms the air in a room, by radiation, conduction, and convection. At night and in winter the air cools by radiation; and contact with the ground is another important cause for cooling.

Vapor and dust interfere with radiation, and for this reason more heat is retained in the lower atmosphere on hazy and muggy days than in clear, dry weather. At such times radiation fails to cool the ground, and a hot, muggy day may be followed by an oppressive, almost stifling night. It is under such conditions that our most oppressive summer weather comes.

Summary. — *The air is warmed somewhat by the passage of heat rays through it, but far more by conduction from the ground, and by convection. It is cooled by radiation, and by conduction from the ground. Vapor and dust interfere with radiation.*

167. Causes for Differences in Temperature on the Earth. — (A) *Position of Sun.* — The sun is higher in the heavens at noon than in early morning and late afternoon; in summer than in winter; and in tropical than in temperate zones. When low in the heavens, the sun's power is less than when high, because (1) the rays pass through a great thickness of dust-laden air when the sun is low (Figs. 392, 394) and (2) fewer rays then reach a given surface (Fig. 393).

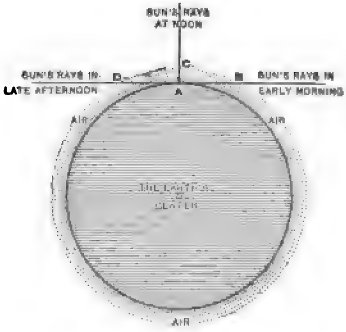

FIG. 392. — To show that the sun's rays pass through more air when the sun is low in the heavens than when it is high.

There are three important results of these different positions of the sun. (1) Every day, as the angle at which the

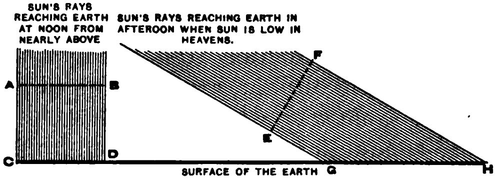

FIG. 393.—Two bundles of rays having the same width (AB and EF); but, owing to the difference in angle at which they reach the surface CH, those that are inclined cover about twice as much ground as those that come straight down from above. Therefore, on the same area there are about half as many inclined rays as vertical.

sun's rays pass through the air varies (Fig. 392), there is a change in the warmth of the sun. (2) As the sun changes position, from high in the heavens to lower, the seasons of summer and winter occur in both hemispheres. (3) Where the sun is highest, that is in the tropical zone, the climate is hottest; and the climate grows cooler away from the equator as the sun gets lower in the heavens (Fig. 394).

Summary. — *When the sun is low in the heavens it warms less than when high, because* (1) *the rays pass through so much air, and* (2) *fewer rays reach a given area. Changes in the sun's position in the heavens from morning to night, from season to season, and from place to place, therefore cause differences in temperature.*

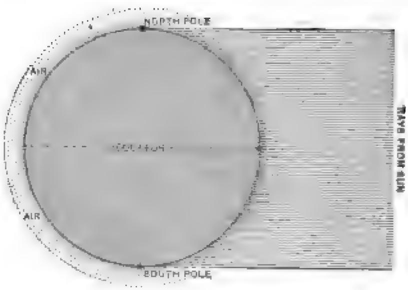

FIG. 394.—To show that near the poles the sun's rays reach the earth in a more slanting way, and after passing through more air, than at the equator.

(B) *Altitude.*—Observations on mountains and in balloons show that, as the elevation increases, there is a gradual decrease in temperature at the rate of about 1° for every 300 feet. There is no warm ground to impart heat to these upper layers of the atmosphere; and warm air, rising from the surface, expands and cools as it rises. Because the upper air is so cool, a frigid climate is found at the equator

at a height of a few miles; and highlands are everywhere cooler than neighboring lowlands.

That air cools on expanding may be proved by a bicycle pump. Air pumped into the tire is compressed, or made more dense, and therefore warmed. When this compressed air is allowed to escape, it expands and cools, and its coolness may be felt.

Although surrounded by cold air, parts of highlands exposed to direct rays of the sun may become quite warm at midday. On a high mountain one may, therefore, be very warm in a protected, sunny place, while a few feet away, in a shady spot, or one exposed to the wind, it is very cold. Radiation is so rapid in the clear, thin, upper layers of air that even the warm places quickly cool off when the sun disappears; in fact, the temperature may rise to 90° at midday and descend to 10° at night.

Summary. — *Highlands are cooler than lowlands, the temperature changing about* 1° *for every* 300 *feet. There is no warm land to warm the upper air, and air cools as it rises and expands. Rapid radiation in the clear, thin air causes cold nights.*

(C) *Other Reasons for Differences.* — We have already learned several reasons for differences in temperature according to situation; for example, nature of rock, exposure (p. 237), and influence of water bodies (p. 238). The nature and direction of the wind also influence temperature (p. 265). These causes for differences in temperature are more fully studied in Chapter XIV.

168. Daily and Seasonal Temperature Changes. — (A) *Daily Range.* — The warmest period is not midday, when the sun is highest, but two or three hours after noon (Fig. 395). The reason for this is that in the morning it is first necessary to warm the ground that was cooled by radiation the night before. After the ground is warmed, the temperature continues

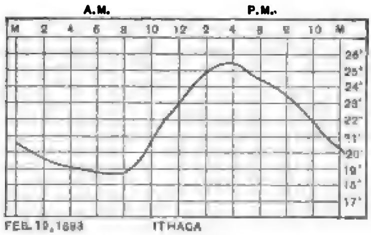

Fig. 395. — Normal daily temperature range in winter at Ithaca, N.Y.

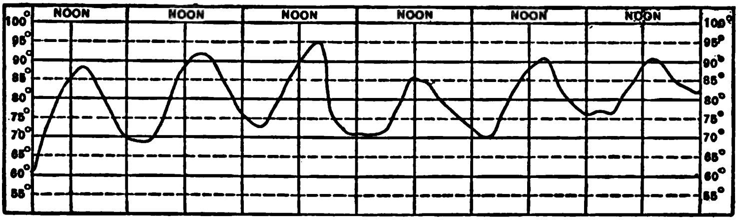

FIG. 396.—Change in temperature for six successive summer days at Ithaca, N.Y.

to rise until the sun has sunk so low that heat is radiated away faster than it is received. Then the ground and air commence to cool, continuing to do so until sunrise. Therefore the coldest period is not midnight, but just before sunrise (Fig. 395). Because of these conditions there is a normal daily change, or range, of temperature similar to that shown in the diagram (Fig. 395).

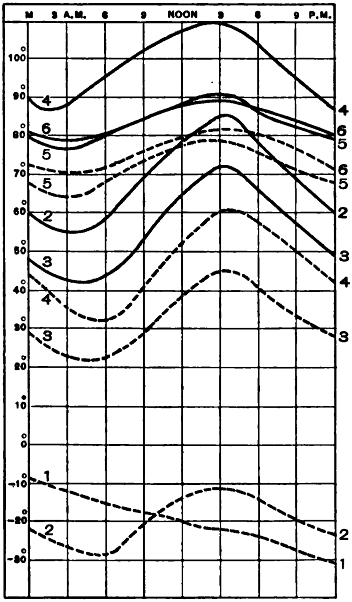

FIG. 397.—Normal summer (heavy line) and winter (dotted line) daily temperature range for several places. (1) Arctic; (2) St. Vincent, Minn.; (3) Djarling, India; (4) Jacobabad, India; (5) Key West, Fla.; (6) Galle, India; 5 and 6 are near the warm ocean.

There are a number of conditions which may occasionally interfere with the normal daily range (Fig. 396). A cloudy sky, interfering with the passage of the sun's rays, may prevent the temperature from rising after noon; or winds may bring such cold air that the temperature falls, even during the daytime; or warm winds may cause the temperature to rise throughout the night.

The amount of change from

day to night differs from time to time and from place to place. Thus the range is great when warm days are followed by cool nights, and less when cool days are followed by cool nights. The daily range in winter is quite different from that in summer; it is different at the equator from what it is in temperate latitudes; and on the land from what it is at sea (Fig. 397).

Summary. — *In the normal daily range the temperature is highest after midday, and lowest just before sunrise. The amount of daily range varies from time to time and from place to place.*

(B) *Seasonal Range.* — The yearly range of temperature closely resembles the daily range. If the average temperature for each day is kept, it will be found that in the northern hemisphere there is a steady rise from March to August, and then a gradual fall until February (Fig. 398). The reason why the coldest weather comes after midwinter (December 21) is that radiation continues to cool the ground and air until the days become long enough, and the sun high enough, to overbalance the effect of radiation. The hottest period of the year comes after midsummer (June 21), for the same reason that the hottest time of day is after noon.

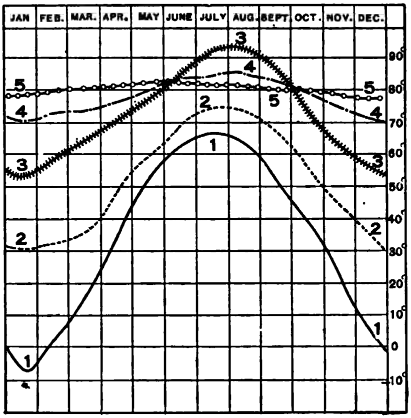

FIG. 398. — Seasonal temperature range in several places. (1) St. Vincent, Minn.; (2) New York State; (3) Yuma, Ariz.; (4) Key West, Fla.; (5) Galle, India; 4 and 5 are near the equable ocean.

While there is a normal seasonal curve as described, it differs greatly in various parts of the world (Fig. 398). For example, the midwinter temperature at the equator is very high, in the frigid zones very low; the range over the equable ocean is far less

than that over the land; in the southern hemisphere the lowest temperature comes at the time of our summer. There are also differences caused by altitude, deserts, and other influences.

Summary. — *The average temperature rises until after midsummer and descends until after midwinter. The normal curve of seasonal temperature range varies from place to place.*

FORMS OF WATER.

169. Humidity. — Water vapor, which rises from the ocean, and all damp surfaces (p. 230), is diffused through the air and drifted about with it. It finds its way to all parts of the earth; not even the Sahara has absolutely dry air. The *actual amount* of vapor in the air, that is, the amount in pounds or quarts, is known as the *absolute humidity.* If there is as much as possible, the air is said to be *saturated.* For example, in a room 10 × 20 × 20 feet, the air at a temperature of 80°, if saturated, has 6¼ pounds of water in the form of vapor. This is its absolute humidity.

To represent the amount of vapor present in air, compared with the amount that might be there, the term *relative humidity* is employed. Relative humidity is measured in percentages. Thus the relative humidity of saturated air is 100 per cent, for it has all it can contain; of absolutely dry air, 0 per cent; and of air having only half as much as it might carry, 50 per cent.

If the relative humidity is low, as in deserts, there is a chance for so much more vapor in the dry air that evaporation is rapid; if the humidity is high, as in the tropical forest, there can be little evaporation, and surfaces remain damp. We notice this difference in summer, for some days are clear and dry, others are humid or muggy. When the humidity is great, the weather is most oppressive; we perspire easily, and are very uncomfortable, because there can be little evaporation from the surface of the body.

Warm air can carry more water vapor than cool air, for the amount of vapor possible depends on temperature. For this reason, when the temperature in the room mentioned above is 60° there can be only 3¼ pounds of water vapor in the air. There is, therefore, far less vapor in the frigid than in the tropical zone.

From this it is evident that if saturated air is warmed, it ceases to be saturated; that is, its relative humidity falls (Fig. 399) and evaporation is possible. This is illustrated by the Sahara. There the winds are blowing toward a warmer region, and the relative humidity is being constantly lowered, causing such dry air that the ground is dried and a desert produced. If, on the other hand, damp air is cooled, its relative humidity increases, and the point is soon reached when it becomes saturated. Further cooling then forces some of the vapor to condense to liquid water, or, if the temperature is below freezing, to snow or ice. This is known as *precipitation.*

These facts explain many phenomena. Thus, when one breathes against a cool window pane the breath is cooled to the point of saturation, and some of the vapor caused to condense. A glass of water "sweats" on warm, muggy days, because the cool glass reduces the temperature of the air near it, and raises the relative humidity to the point of saturation. Then some of the vapor must condense. This point of saturation is often called the "dew point," because, when it is reached, dew forms on the ground. Precipitation is caused whenever the air is chilled to the dew point.

Summary. — *Absolute humidity is the actual amount of water vapor in the air at a given time; relative humidity is the percentage present compared to what might be present at that temperature. The relative humidity decreases with rising temperature, and increases with falling temperature. When it decreases, evaporation becomes more rapid; when it increases, if it reaches the point of saturation, or the "dew point," there is precipitation.*

170. Dew and Frost. — (A) *Dew.* — At night the lower air is chilled by contact with the ground, which is cooled by radiation. If the air is damp, some of the vapor is then condensed as dew; and if it is *very* humid, dew may begin to form even before sunset. The formation of dew is checked (1) when the air is quite dry, (2) when winds stir the air and keep it from reaching the dew point, or (3) when radiation is interfered with by clouds.

One reason why dew forms so readily on grass is that vegetation is a good radiator and hence cools quickly. Another reason is that there is water rising from the plants, as there is also, to less extent, from the ground. During the day this water disappears by evaporation and is, therefore, unnoticed; but at night, when the air is saturated, evaporation is so checked that the water gathers on the surface of the leaves and grass.

Summary. — *Dew is caused* (1) *by the chilling of air to the dew point by the cool ground, and* (2) *by the rising of water from plants. Dry air, winds, and clouds are unfavorable to the formation of dew.*

(B) *Frost.* — Frost is not frozen dew, but the solid form assumed when vapor condenses at temperatures below freezing. Even when the general temperature is above freezing, frost may visit some localities. Low, swampy ground is first affected because (1) the air is damper, and (2) air cooled on the hillsides slides down to these low places.

Sometimes frost comes so early in the fall that fruit not yet quite ripe is destroyed; and late spring frosts often do great damage to buds. Such frosts occur during nights when the air is so clear that radiation proceeds readily. Frosts cause the leaves to change color, and finally to fall; then for a time the trees are dormant, bursting forth into new life with the return of warmth in the spring. Many plants are killed by the first frost, leaving only their seeds, bulbs, or roots to grow the next season.

Summary. — *Frost is the solid form assumed by condensed vapor at temperatures below freezing. Frosts first occur in low, damp places; and early fall and late spring frosts do damage to plants.*

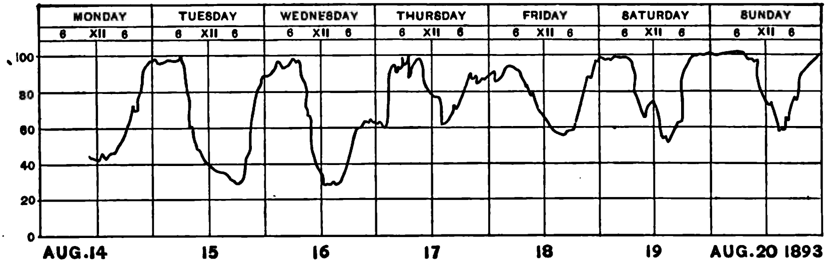

FIG. 399. — Daily changes in relative humidity at Ithaca, N.Y., for one week. Notice that at night the humidity rises nearly or quite to the dew point (100 per cent), but in the warmest part of the day is very low. This does not mean any change in the absolute humidity, but is the result of changes in temperature from day to night.

FIG. 400. — Above the clouds, mountain tops projecting through.

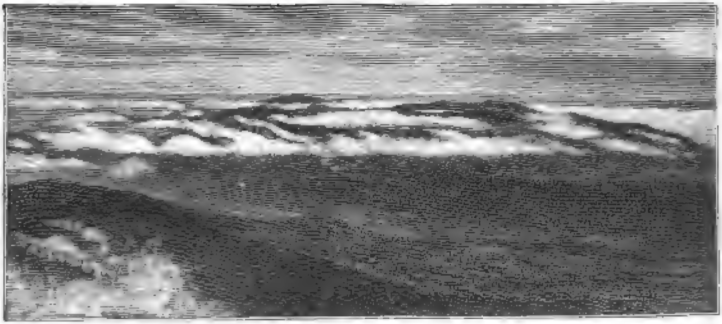

FIG. 401. — Clouds forming on a mountain side. Damp winds blowing upon the cold mountain slopes are here chilled until the dew point is reached.

Alto-cumulus (or high cumulus) in rolls.

Cirro-cumulus.

Cumulus.

Cirrus.

FIG. 402. — A group of cloud pictures.

171. Fog and Clouds. — (A) *Fog.* — When we breathe into cold air, the vapor of the breath is condensed into particles of water so small that they float, forming a tiny fog. Fog is formed when damp air is chilled in other ways. For example, it often forms at night when the air over low, damp land is chilled to the dew point; or it may form when two currents of air are mixed, one cool, the other damp and warm. Fogs at sea are often caused in this way.

One of the foggiest places in the world is on the path of transatlantic steamers south of Newfoundland. Here the warm Gulf Stream drift and the cold Labrador current are near together; and winds from one to the other cause vapor to condense into fog particles. Vessels rarely pass the Banks of Newfoundland without encountering some fog; and in it many a boat has been lost by collision with another, or with an iceberg, or by running aground on the shoals. Fog is one of the most dreaded dangers of the sea, and cautious captains reduce their speed, and keep the fog-horns blowing to warn other vessels of their approach. In harbors, navigation is sometimes completely stopped by dense fogs.

Dust particles, by supplying solids on which the water may collect, aid in the formation of fog. It is believed that the fogginess of London is partly due to the large amount of dust in the neighborhood of that great city. The fog of London is sometimes so dense that it is necessary to stop all traffic on the streets, and even to close the stores.

Summary. — *Fog is caused by the chilling of air to the dew point, forcing some of the vapor to condense to tiny drops. Dust particles supply solids for the water to condense on.*

(B) *Clouds.* — Clouds are also made by the condensation of vapor. Most clouds are fog or mist, though the higher ones, where the temperature is below freezing, are composed of snow or ice particles. Many clouds, especially on summer days, are caused by the rising of warm, damp air. As the air rises it expands and cools; and when the dew point is reached, fog particles grow, forming clouds. Clouds are also

caused when damp air blows against a cold surface, for example, a mountain slope (Fig. 400). Still another cause for clouds is the contact of two currents of air, one above the other, one cold, the other warmer and humid.

Clouds assume many weird and beautiful forms (Fig. 402). Those that overspread the sky, having the appearance of layers, or strata, are called *stratus* clouds. They are common during stormy weather, and are usually low in the sky, often so low that they hide the tops of the hills. Frequently, especially in winter, they cover hundreds of square miles and last two or three days, while from them large quantities of rain fall.

The clouds formed by the rising of air on warm summer days are called *cumulus* clouds (Fig. 402). A flat base, usually several thousand feet above the surface, marks the height at which the rising vapor begins to condense. Extending above this base, sometimes to a height of a mile, are a series of cloud domes which are often very beautiful, especially when lighted and colored by the rays of the setting sun. Cumulus clouds often develop into thunder-heads.

A third common type is the *cirrus* cloud (Fig. 402), which is often five or six miles above the surface. Unlike the other two types, these clouds are made of transparent ice particles; and they are so thin that the sun shines through them. It is in cirrus clouds that rings around the sun and moon are often seen (p. 233). The cirrus clouds vary greatly, some having a most delicate and beautiful feathery and plumed form.

There is every gradation between the three types of clouds. To these intermediate forms compound names are given as follows: cirro-stratus, strato-cirrus, cirro-cumulus, cumulo-cirrus, cumulo-stratus, and strato-cumulus. Rain clouds are called *nimbus*.

Summary. — *Clouds are made of fog, mist, snow, and ice particles. They are caused by the condensing of vapor from various causes, — rising and expanding, blowing against cold surfaces, and contact of cold and warmer, damp currents. Stratus clouds are low, and spread over large areas; cumulus clouds rise in domes above a flat base; cirrus are thin, fleecy clouds high in the air and are made of ice particles. There are many variations between these types.*

172. Rain, Snow, and Hail. — (A) *Rain.* — Fog particles in clouds may grow to such size that they can no longer float. They then fall as raindrops. The growth of raindrops is due to several causes: (1) continued condensation of vapor; (2) union of fog particles, driven together by currents of air; and (3) union of particles as they fall through the cloud. Thus rain is merely the result of a continuation of the process of cloud formation. If the vapor condenses rapidly, as in summer thunder-clouds, the drops may grow to great size.

Rain may evaporate on its way from the clouds and fail to reach the ground. Such streamers of rain, descending part way to the earth, may sometimes be seen in summer. In other cases, rain on its way down may freeze in passing through a cold layer of air, forming *sleet*. Some sleet is snow that has partly melted, and then frozen before reaching the ground.

Summary. — *Continued condensation of vapor in cloud formation, and the union of the fog particles, form raindrops so heavy that they must fall to the earth.*

(B) *Snow.* — Snowflakes are not frozen raindrops, but are formed when vapor is condensing in a cloud at temperatures below freezing point. If the snowflake grows without interference, it is a regular and beautiful crystal (Fig. 403). It grows as regularly as salt or alum crystals in a solution that is slowly evaporating. The feathery frost on window panes is also caused by crystal growth, when vapor condenses at temperatures below the freezing point.

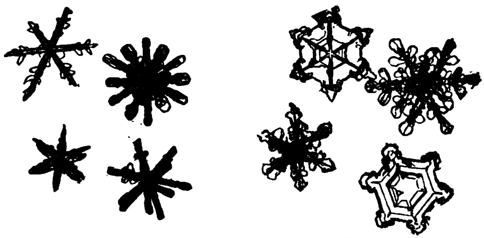

FIG. 403. — Snow crystals.

There are several reasons why snowflakes are usually irregular: (1) the crystals are often broken; (2) several are often united,

forming a matted mass; (3) as the snow falls it is sometimes partly melted in passing through a warmer layer of air. In many cases snow melts entirely, reaching the ground as rain. This is often illustrated in hilly countries, when hilltops are covered with snow while 100 or 200 feet lower, in the valleys, rain is falling.

Summary. — *Snowflakes are crystals, built up by the condensing of vapor at temperatures below freezing. They are often broken, matted, or partly melted on the way down, becoming irregular.*

(C) *Hail.* — Hail is formed in violent storms, such as tornadoes and thunder-storms, where there are strong, whirling currents of air. Hailstones are balls of ice, built up by condensing vapor as they are whirled up and down in the violent currents, freezing, melting, and freezing again as they pass from warm to cold currents. For this reason they are often made of several layers, or shells, of ice. They may grow to great size, and be kept suspended by the uprising currents long after they are heavy enough to fall through quiet air. When they fall, usually at the margin of a storm, they often break window glass and do great damage to crops. Conditions favoring the formation of large hailstones are fortunately not common, and their effects are confined to very limited areas.

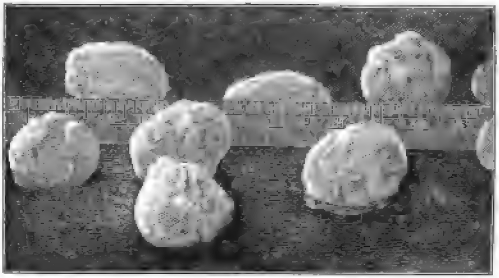

Fig. 404. — Hailstones. Compare with the inches on the ruler.

Summary. — *Hailstones are made of ice, formed by condensing vapor in whirling air currents. They may grow to large size before they fall, then often doing considerable damage.*

TOPICAL OUTLINE, QUESTIONS, AND SUGGESTIONS.

TOPICAL OUTLINE. — 162. **Composition of the Air.** — (A) *Oxygen, Nitrogen, and Carbon Dioxide:* percentage of each; argon; importance of oxygen; of nitrogen; of carbon dioxide; slow combustion in animals; rapid combustion; production of heat. (B) *Water Vapor:* source; evaporation; variation in amount; condensation. (C) *Dust Particles:* nature of materials: distribution; effect on condensation; microbes.

163. **Effect of Gravity.** — Cause of weight; amount at sea level; reason for not noticing pressure; density of lower air; rarefied air; effect; effect of temperature on density of air; movements started by gravity.

164. **Light.** — Nature of light; speed of passage; combination of waves; effect of prism; refraction; colors of spectrum; reflection; instances; mirage; rainbow; halos; color of objects; diffraction; blue color of sky; sunset colors.

165. **Heat.** — (A) *Radiant Energy:* heat from a stove; light from a stove; radiant energy; radiation; radiant energy from bodies in space; effect of radiation on stove; on sun; part reaching earth. (B) *Passage of Radiant Energy:* diathermanous; effect of air on heat; effect of dust. (C) *Radiation from the Earth:* earth as a radiator; cause of cool nights; of cold winter; difference between land and water; difference in frost. (D) *Reflection and Absorption:* water; quarries; black objects; white objects. (E) *Conduction:* in a stove; air, water, and ground as conductors; depth of conduction in the ground. (F) *Convection:* in water; in air, — near a lamp, near a fire, by heat from sun.

166. **Warming of Land, Water, and Air.** — (A) *The Lands:* warming; loss of heat; day and night; tropical zone; temperate zone; frigid zone; color of surface; vegetation; exposure. (B) *The Waters:* comparison with land; heat of vaporization; equable climate. (C) *The Air:* causes for warming; causes for cooling; interference with radiation.

167. **Causes for Differences in Temperature on the Earth.** — (A) *Position of Sun:* differences in height; reasons why sun low in heavens is less powerful; results. (B) *Altitude:* decrease in temperature; explanation; illustration of effect of expansion; sunny spots; effect of radiation. (C) *Other Reasons for Differences:* rock; exposure; water; wind.

168. **Daily and Seasonal Temperature Changes.** — (A) *Daily Range:* warmest period; coolest period; reasons; interference with normal range; difference in amount of range. (B) *Seasonal Range:* resemblance to daily range; coldest period; warmest period; reasons; causes for differences in curve.

169. **Humidity.** — Source; distribution; absolute humidity; saturated air; relative humidity; measuring relative humidity; effect of low humid-

ity; of high humidity; influence of temperature on humidity; cause of deserts; precipitation; illustrations of effect of cooling; dew point.

170. **Dew and Frost.** — (A) *Dew:* cause; unfavórable conditions; reason for dew on grass. (B) *Frost:* cause; most favorable places; early and late frosts; effect of frost on plants.

171. **Fog and Clouds.** — (A) *Fog:* the breath; chilling of air; fog off Newfoundland; dangers to navigation; aid of dust particles; London fog. (B) *Clouds:* materials; causes; stratus; cumulus; cirrus; intermediate forms; nimbus.

172. **Rain, Snow, and Hail.** — (A) *Rain:* reason for falling; causes for drops; large drops; failure to reach earth; sleet. (B) *Snow:* cause; snowflakes; frost on windows; irregularity of snowflakes; melting of falling snow. (C) *Hail:* formation; reason for shells of ice; size; effects.

QUESTIONS. — 162. (A) What elements make up the bulk of the air? What is the importance of each? (B) What is evaporation? What difference is there in the amount of vapor in air? What results when it is condensed? (C) What are dust particles? Where are they most common? What are their effects?

163. Has air weight? Why? How much? Why does not the weight of the air affect us? In what two ways does the density vary?

164. What is light? What is refraction? What is reflection? What phenomena are produced by reflection and refraction of light in its passage through the atmosphere? What is the cause of color in flowers? What is the cause of the blue color of the sky? Of sunset colors?

165. (A) What is radiant energy? What is radiation? What effect is radiation having on the sun? (B) What are diathermanous bodies? Give examples. Why does the sun lose power in late afternoon? (C) Why does the ground become cool at night and cold in winter? What difference is there in the radiation of bodies? (D) Give illustrations of reflection. Give illustrations of absorption. (E) What is conduction? What effect has it on earth, air, and water? (F) What causes convection in water? Give illustrations of convection of air.

166. (A) Why is not the ground excessively warmed? What differences are there in the three zones? What other causes for difference are there? (B) State the reasons why water warms more slowly than land. What is heat of vaporization? Compare land and water in winter and at night. What is an equable climate? (C) How is the air warmed? How is it cooled? Why is muggy air oppressive?

167. (A) Why is the sun less powerful when low than when high? State three important effects of differences in sun's position. (B) Why are highlands cool? Are any parts warm? What is the effect of radiation? (C) What other reasons are there for differences in temperature?

168. (A) When are the warmest and coolest times of day? Why? What causes are there for interference with the normal daily range? For differences in the amount of daily range? (B) When are the warmest and coolest times of the year? Why? What reasons are there for differences in the normal seasonal curve?

169. What is absolute humidity? What is saturated air? What is relative humidity? What is the result of raising the temperature? What is the cause of some deserts? What is the result of lowering the temperature? What causes precipitation? Illustrate. What is dew point?

170. (A) What is the cause of dew? Under what conditions is there no dew? Why is there so much dew on grass? (B) What is frost? Why does frost first visit low, damp places? What are its effects?

171. (A) What are the causes for fog? What are the conditions on the Banks of Newfoundland? Why? What is the effect on navigation? What relation have dust particles to fog? (B) Of what are clouds made? How are they caused? Name and describe each of the cloud types.

172. (A) What is the cause of rain? Why do the drops vary in size? What is sleet? (B) What are snowflakes? How formed? Why are they often irregular? (C) What is the cause of hailstones? Why do they sometimes grow so large?

SUGGESTIONS. — (1) Recall Experiments 1, 2, 3, 4, and 6 of Chapter II, p. 30. (2) Let a beam of sunlight enter a darkened room and notice the dust that it lights. Watch the sky to see if it is sometimes hazy. Is it clearer after a rain? Why? (3) By means of an air pump show that air has pressure. The teacher of physics can tell how this is to be done. (4) Obtain a prism of glass from the physical laboratory and allow a ray of sunlight to pass through it in order to study the prismatic colors. (5) Place a stick in water and notice that it appears to bend below the water. This is due to refraction. (6) Heat a brick or a stone and suspend it by a wire. Why does it become cool? Does the thermometer show rise of temperature when placed near it? Why? (7) Try the experiment with black and white cloth, mentioned on p. 236, using ice instead of snow. (8) Place a thermometer in the shade in such a position that sunlight can be reflected on it by means of a mirror. Does the temperature rise? (9) Place one end of a bar of iron in the fire. Does the other end become warm? Why? Place an equal bulk of several substances — for example, iron, soil, and rock — on the stove for a short period to test which first becomes warm by conduction. Use a thermometer to determine this. It can also be told by putting a thin layer of paraffin on each, noticing on which it first begins to melt. (10) Study convection in water, using a glass dish with muddy water so as to see its movement. Study the convection of air near a lamp, clouding the air with smoke (this can be obtained by

lighting a piece of cloth) so that its movement may be seen. Explain the principle of a lamp; of a fireplace. How is your schoolhouse ventilated? Does the fresh air come in above or below? Why? (11) Place a brick and a pan of water (as deep as the thickness of the brick) on a hot stove or over a Bunsen burner. Carefully weigh each before placing them there. When the brick has become warm, take the temperature of each at the top. At the bottom. Why is one the same temperature throughout, the other hot at the bottom and only warm at the top? Which shows the higher temperature? Why? When cool, weigh them again. Has either lost weight? Why? (12) Do the same with water and soil, leaving a thermometer in each and recording the changes. In which does the temperature rise faster? Which cools faster? (13) Take the temperature at 6, 8, 10, 12, 2, 4, 6, 8, and 10 o'clock for one day. Construct a curve similar to Fig. 395. Keep records for a week, and construct curves to see if they are all alike. (14) A seasonal curve can also be made, getting the data from the Annual Report of the United States Weather Bureau, in which daily averages are given for many places. (15) With a bicycle pump illustrate the warming of air by compression, and cooling by expansion (p. 241). A little fog can be produced by placing a dish of hot water where the escaping cool air passes over it. (16) Make observations on condensation, — blowing on a cold window, for example. In warm, damp air, watch drops collect on a glass of ice water. That the water does not come from within the glass may be proved by placing a glass, without water, on ice until it is cold, then putting it in the room. The same thing may also be shown by putting salt and ice in a bright tin dipper. The temperature of dew point can be determined by putting a thermometer in the salt and ice, reading the temperature at the moment water begins to cloud the surface of the dipper. (17) Study frost: the time of its coming; the places where it comes first; and any other facts you can find out by observation. (18) For a few days observe the clouds carefully, classifying those you see.

Reference Books. — DAVIS, *Elementary Meteorology*, Ginn & Co., Boston, 1894, $2.70; WARD, *Practical Exercises in Elementary Meteorology*, Ginn & Co., Boston, 1896, $1.12; WALDO, *Modern Meteorology*, Scribner's Sons, New York, 1893, $1.50; *Elementary Meteorology*, American Book Co., New York, 1896, $1.50; RUSSELL, *Meteorology*, Macmillan & Co., New York, 1894, $4.00; TYNDALL, *The Forms of Water*, Appleton & Co., New York, 1872, $1.50; *Illustrative Cloud Forms*, U. S. Hydrographic Office, Washington, 1897, $1.00; *Annual Reports* and *Monthly Weather Reviews*, U. S. Weather Bureau, Washington; BARTHOLOMEW, *Physical Atlas*, Vol. III, *Meteorology*, Archibald Constable, London, 1899, $13.00.

CHAPTER XIII.

WINDS AND STORMS.

WINDS.

173. Relation between Winds and Air Pressure. — Winds are the result of differences in the air pressure, or weight. It is easier to understand their cause if we consider the atmosphere to be composed of a great number of air columns which gravity holds to the earth. If the sun's heat warms the air in one place, the columns at that place become lighter than in places not so warmed (p. 231). Light air is said to have a *low pressure*, heavy air a *high pressure*, because the heavier the air, the higher it pushes the mercury up in the tube of the barometer (Appendix G). The air moves, or flows, from places of high toward places of low pressure, thus causing winds. On a larger scale, it is much the same as the movement of the cooler and heavier air which crowds up the warm, lighter air in a lamp (p. 236).

The difference in air pressure which causes winds is often known as the *barometric gradient.* It is so named because the air flows from a region of high pressure, or high barometer, to one of low, as if it were going down a grade, or gradient, as flowing water does. It is not to be understood, of course, that there is a real slope or grade, but merely lighter air in one place than in another. If the difference in pressure is great, the barometric gradient is so high that the air moves swiftly, as water flows down a steep grade.

Summary. — *Winds are due to a flowing of air from regions of heavy air, or high pressure, to regions of low pressure; and the difference in pressure is known as the barometric gradient.*

174. Sea and Land Breezes. — A simple illustration of winds is often found along ocean and lake shores on hot days. On such days the land, and the air over it, become much warmer than the water (p. 238). Soon the heavier air from the water flows in as a cool, refreshing *sea breeze*, pushing upward the warm, lighter air that rests on the land.

When the sea breeze begins to blow, the temperature, which may have risen to 80° or 90°, commences to fall, and the rest of the day is pleasantly cool. It is partly because of the cool sea breezes that so many people go to the seashore to spend their summer vacations. Along tropical coasts, sea breezes are very pronounced and of almost daily occurrence.

At night a *land breeze* often blows out over the water. The reason for this is that the land cools by radiation faster than the water (p. 238), and the cool land air slides out over the sea, pushing up the warmer air that rests there. Sailboats, becalmed offshore when the sea breeze dies down, are able to reach port late in the evening when the land breeze begins to blow.

Summary. — *Sea breezes are caused by cool air from the sea flowing in on hot days and pushing up the warm, light air over the land. At night, land breezes blow out over the sea from the cooler land.*

175. Mountain Valley Breezes. — Winds similar to the land breezes are noticed at night in hilly and mountainous regions. As the land cools by radiation, the cool, heavy air slides down the slopes, causing winds that often gain great force late at night. During the day, as the valley sides are warmed, the air moves up the valleys; but this movement does not cause such strong winds as those at night, when the air is flowing down grade and gathering from many tributary valleys into one main valley.

Summary. — *At night, cool air slides down valleys, forming winds; and air passing up the valleys during the day causes lighter breezes.*

176. Monsoon Winds. — On some of the continents, there are changes in wind direction from summer to winter. These seasonal winds, known as *monsoons*, are best developed in Asia (p. 259).

In summer the land becomes warmer than the water, and air, therefore, blows from the Pacific and Indian oceans toward the warm interior, forming the summer monsoon. In winter, when radiation cools the Asiatic highlands, the heavy air

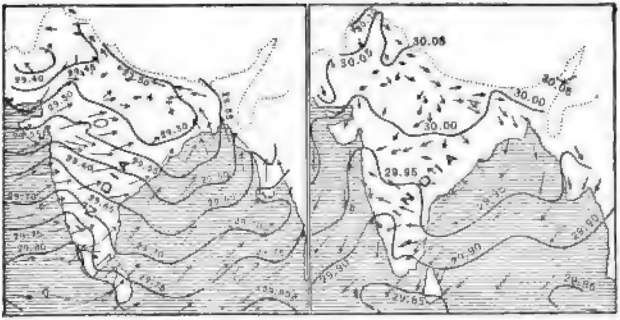

FIG. 405. — The summer (left hand) and winter (right hand) monsoons of India.

moves outward toward the warmer oceans, forming the winter monsoons. Thus twice each year the winds change. In India the changes are so regular, and the winds so steady, that early sailing vessels went there in summer and came away in winter, in order to have fair winds both ways.

All continents show some tendency toward the development of monsoon winds; but in most cases other winds are too well established for the monsoons to develop perfectly. For example, the regular winds of northeastern United States are from the west; but they are much steadier in winter than in summer (Figs. 409, 410). The reason for this is that in winter the outflow of cold air from the land strengthens the west winds, while in summer the inflow of cool air from the ocean weakens them; but the summer inflow is not strong enough to completely destroy the west wind movement and form regular monsoons.

Summary. — *Monsoon winds, best developed in Asia, are due to the inflow of air from the ocean to the warmer land in summer, and the outflow of air from the cold land in winter.*

177. Wind Systems of the Earth. — Even greater air movements than those just described are caused by differences in temperature between the warm tropical belt and the cooler zones north and south of it. The winds thus started affect all zones, all continents, and all oceans.

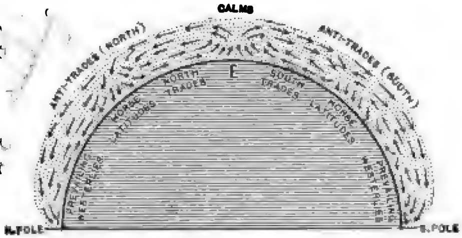

Fig. 406. — A diagram to illustrate the circulation of the earth. *E* is equator.

(A) *Comparison with a Stove.* — In certain respects this great circulation may be compared to the movements of air in a room heated by a stove. The air around the stove is warmed, and the cooler, heavier air in other parts of the room crowds in and pushes the warm air upward. There is, therefore, (1) a movement toward the stove; (2) a rising above it; (3) an upper current away from it; and (4) a settling at a distance from it.

Because of the heated belt of the tropical zone there are similar movements on the earth (Fig. 406). These are (1) a movement of air along the surface toward the equator; (2) a rising in the torrid zone; (3) an upward movement away from this zone; and (4) a settling north and south of it.

Summary. — *Both in a room heated by a stove, and on the earth, warmed in the torrid zone, there is a movement of air toward the warm place, a rising, an outflow above, and a settling.*

(B) *Effect of Rotation.* — While air currents in a room move straight toward the stove, the winds of the earth are gradually turned from a straight course by the influence of the earth's rotation. Currents of air, like water (p. 191), are turned, or deflected, in the northern hemisphere toward the right, in the southern toward the left. This effect of rotation is therefore called *right-hand deflection* in the northern hemisphere, and *left-hand deflection* in the southern.

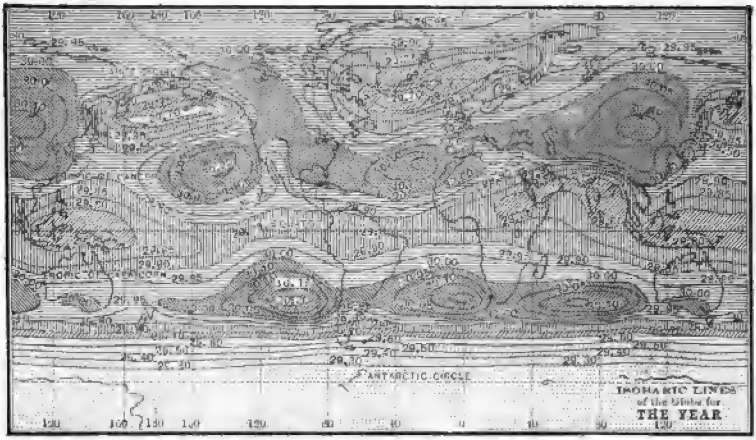

FIG. 407.—Isobars (lines of equal pressure) for the world. The dark shading represents high pressure. The figures (29.85 for example) are inches to which the mercury in a barometer rises, being highest where the air pressure is greatest. In the dark zones of high pressure, the horse latitude belt, air is settling; it moves thence toward the low pressure belt of the warm torrid zone, forming the trade winds, and toward the low pressure areas near the poles, forming the prevailing westerlies.

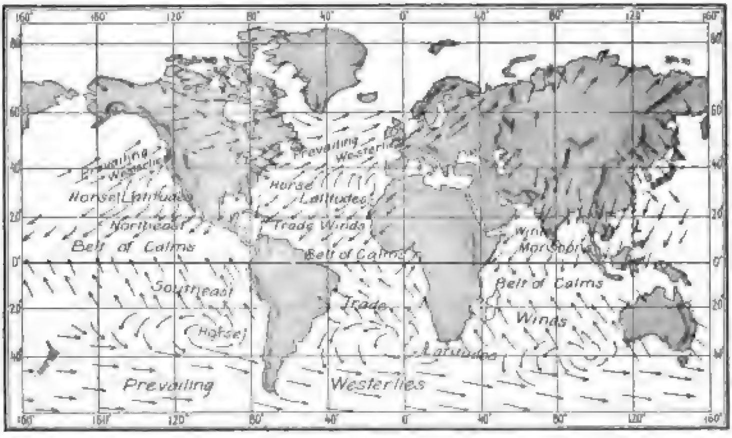

FIG. 408.—A sketch map showing the prevailing winds and wind belts of the earth in winter.

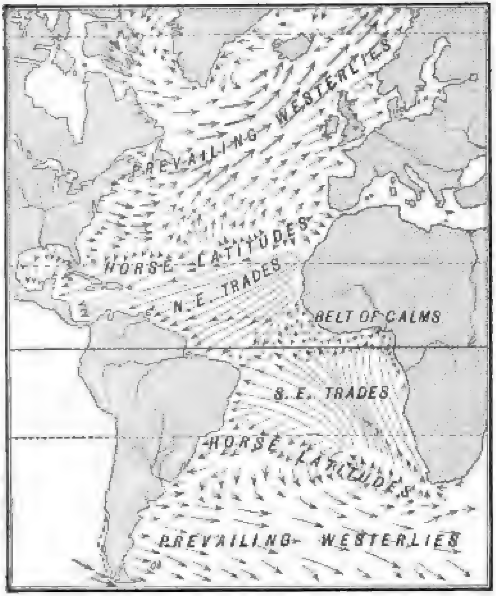

FIG. 409. — Wind belts of the Atlantic in winter. Compare with Fig. 410 to see migration of the wind belts. Length of arrows indicates steadiness; double line, strong winds; circles, calms.

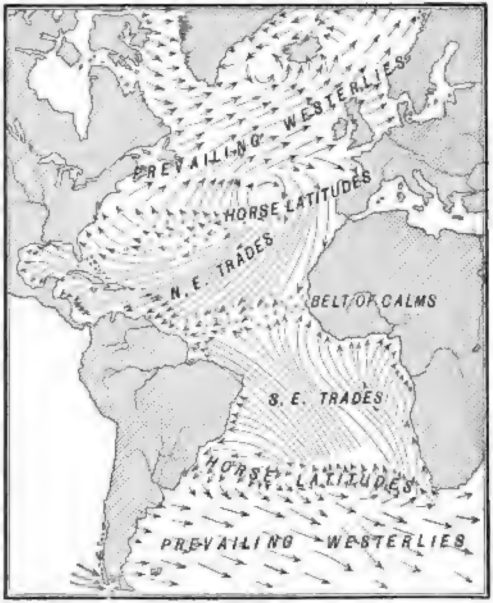

FIG. 410. — Wind belts of the Atlantic in summer. Notice how much more poorly the prevailing westerlies are developed than in winter (Fig. 409), when cold air from the interior flows outward from North America.

Summary. — *The effect of the earth's rotation turns winds toward the right (right-hand deflection) in the northern hemisphere, and toward the left (left-hand deflection) in the southern.*

(C) *Belt of Calms.* — In the torrid zone, where the air is rising, there is little wind, because the air movement is vertical (Fig. 406) instead of horizontal. This is a region of baffling calms, sometimes called the *doldrums*, sometimes the *belt of calms* (Figs. 408–410). This belt does not remain stationary, but, as the belt of greatest heat changes position with the season (Figs. 439, 440), migrates northward and southward.

Summary. — *Where the air is rising, in the torrid zone, there is a region of calms which changes position with the season.*

(D) *Trade Winds.* — The air currents that move toward the belt of calms, known as the *trade winds* (Figs. 406, 408–410), blow with great steadiness, especially over the ocean. Indeed, islands in the trade-wind belts commonly have steep, wave-cut cliffs on the windward side, against which the surf is ever beating. Instead of blowing directly from the north in the northern hemisphere, and from the south in the southern, the trades are deflected by the influence of rotation, becoming northeast winds in the northern hemisphere and southeast in the southern. These are, therefore, called the *southeast trades* and *northeast trades* respectively.

As the belt of calms migrates northward and southward each season, the trade winds also change position, being farther north in summer than in winter. For this reason, places near the border of the trade-wind and calm belts have alternate seasons of calms and trade winds (Figs. 439, 440).

The reason why the monsoons are best developed in Asia (p. 257) is the nearness of the belt of calms. The winter outflow of cold air strengthens the northeast trades; but in summer, when the belt of calms has migrated northward to the land, the southeast trades extend across the equator to the land. That is,

in summer the land is so warm that, in this region, the southeast trades are strengthened and the northeast trades destroyed.

Summary. — *The steady movement of air toward the torrid zone forms the trade winds, which, deflected by rotation, blow from the northeast in the northern hemisphere and the southeast in the southern. These belts migrate northward in summer, southward in winter.*

(E) *Antitrades.* — The air that rises in the belt of calms flows northward and southward, high above the earth (Fig. 406). Turned by the influence of rotation, these upper currents, or *antitrades*, move from the southwest in the northern hemisphere and from the northwest in the southern hemisphere; that is, opposite in direction to the lower trade winds. The movement of higher clouds, and of ash erupted from volcanoes, proves this. On high peaks which rise above the trade winds, as in the Hawaiian Islands, the antitrades may be felt.

Summary. — *The outflow of air that rises in the belt of calms is known as the antitrades, which blow above the trades.*

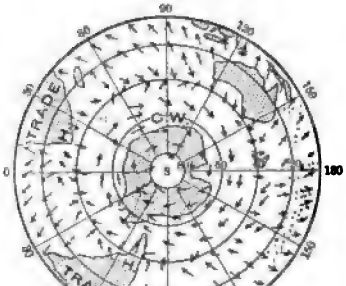

FIG. 411. — Ideal circulation of air near the surface in the southern hemisphere. Trade = trade-wind belt. *H, H* = horse latitudes. *C. W.* = circumpolar whirl.

(F) *Prevailing Westerlies.* — On its way toward the poles some of the upper air settles to the surface, but much continues on to high latitudes. There is, therefore, a movement of air from a broad belt in the torrid zone toward the small area around each pole. It may be compared to the movement of water toward the small outlet of a wash basin. In its attempt to reach this outlet the water commences to whirl about it; and, in a similar way, the air forms a whirl about each pole known as the *circumpolar whirl* (Fig. 411).

The direction that this whirl of air takes is determined by the influence of rotation; that is, the air currents are turned toward the right in the northern hemisphere and toward the left in the southern. This causes winds from a westerly direction in each hemisphere. Therefore these wind belts are called the *prevailing westerlies* (Figs. 406, 408–411). They cover the greater part of the two temperate and the two frigid zones.

These winds, as well as the others, are interfered with by various causes. For example, they are often strongest during the day, because of differences in pressure, caused by the ~~warmth~~ of the sun. When the sun sets the wind often dies down. Storms, sea breezes, and the effects of topography, such as the influence of valleys, also interfere with the force and direction of the winds.

Winds are commonly less steady and strong on land than on water. The reason for this is that the roughness of the land, and its differences in temperature, interfere with their movement. Since in the southern hemisphere there is so little land to interfere with the regular winds, the prevailing westerlies are better developed there than in the northern hemisphere (Figs. 408–411). Indeed, in the great Southern Ocean, a vessel can sail eastward around the earth with prevailing fair winds.

There is so much land in the northern hemisphere that the westerlies are greatly interfered with; but high in the air, above the influence of the surface, they blow with great strength and steadiness. Any one can prove this for himself by watching the upper clouds and noticing how uniformly they move eastward, even when the wind at the surface is from the opposite direction.

Summary. — *Some of the air of the antitrades continues on, forming the circumpolar whirls. Turned by the influence of rotation, these winds blow from westerly directions in both hemispheres, forming the prevailing westerlies. They are better developed over the Southern Ocean, and high in the air, than at the surface of the northern hemisphere, where they are interfered with by irregular land and by local winds.*

(G) *Horse Latitudes.* — Between the trades and westerlies, in each hemisphere, there is a belt known as the *horse latitudes*,

in which the air of the antitrades is steadily settling (Figs. 406, 407). Since the air movement is vertical, this is a belt of relative calm, with irregular, unsteady winds, quite in contrast to the steady trades on one side and west winds on the other (Figs. 408–410). As the belt of calms and the trade-wind belts migrate northward and southward with the seasons (p. 259), the horse latitude belts also shift.

Summary. — *The horse latitudes are belts (one in each hemisphere) of relative calm, where the air of the antitrades is settling.*

STORMS[1]

178. Cyclonic Storms. — (A) *Characteristics.* — The United States weather map (Fig. 413) shows an area where the air pressure is light. It is, therefore, called a *low pressure area*, or a *Low* (p. 255). Around this center of low pressure the mercury in the barometer stands higher, and this fact is indicated by lines of equal pressure, or *isobars*. Air is moving

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FIG. 412. — Diagram showing theoretical movement of air (by arrows), and other conditions, in a low pressure or cyclonic storm area. Describe this diagram.

from all directions toward the low pressure area. Next day (Fig. 414) the Low has moved eastward; but winds still blow toward it, and around its center rain falls. This area of low pressure is known as a *cyclonic storm*. The following day the storm has moved still farther east (Fig. 415), and, if we should continue to follow it, we could trace it out into the Atlantic, and possibly even across northern Europe into Asia.

Summary. — *A cyclonic storm is an area of low air pressure toward which winds blow from all directions, and in which rain falls. Such storms move eastward.*

[1] See also Appendix H, and pp. 289–293.

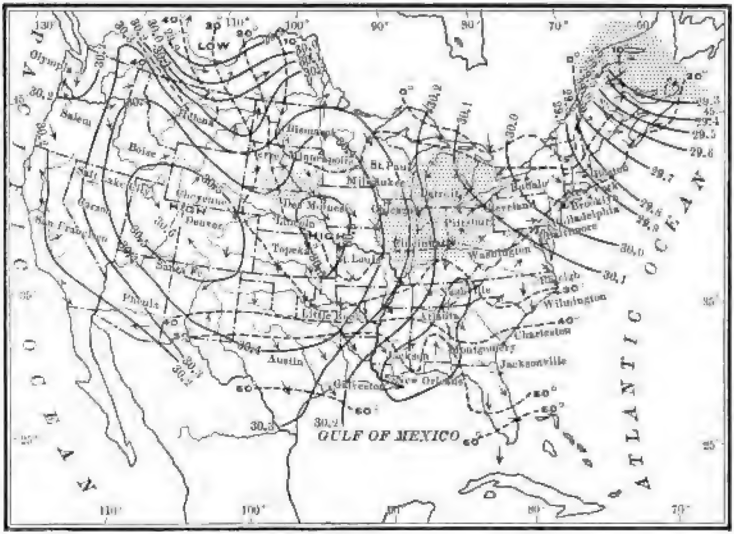


FIG. 413. — Chart to show weather conditions, January 7, 1893. Isobars, heavy lines; isotherms dotted; wind's direction indicated by arrows; areas of rain shaded. Compare with Figs. 414 and 415.

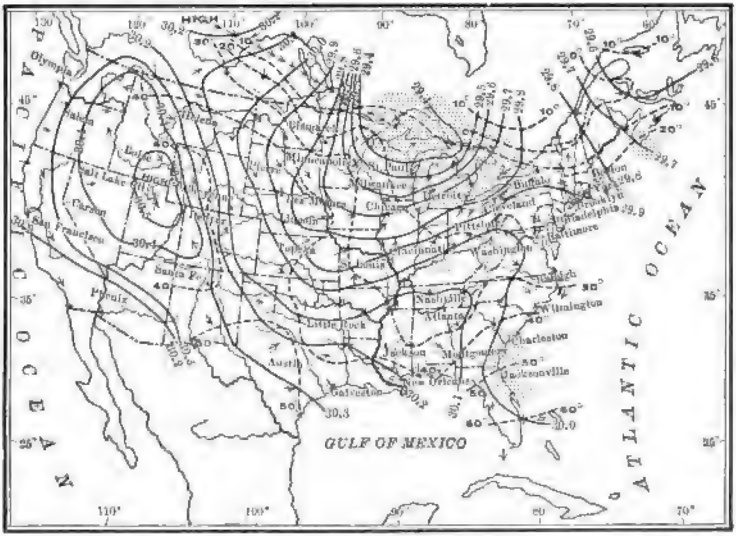


FIG. 414. — Weather map for next day, January 8, 1893. Path pursued by storm center indicated by chain of arrows.

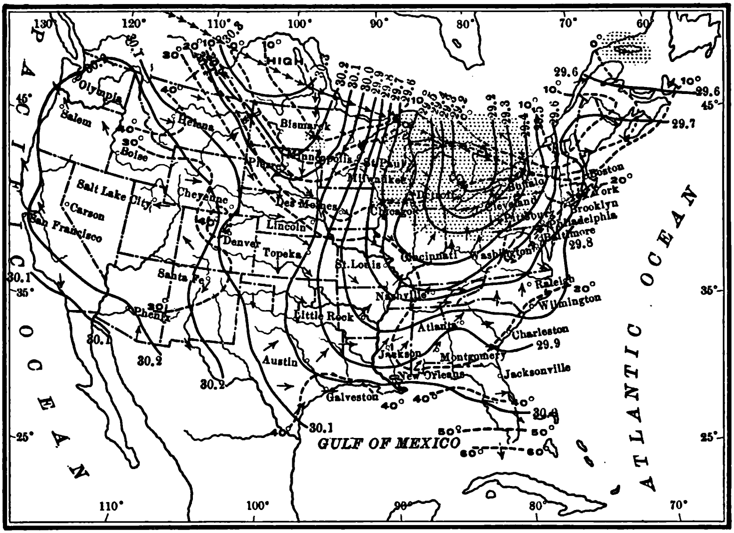


FIG. 415. — Same storm as Figs. 413 and 414, showing its position on January 9, 1893. Trace the changes for these three days.

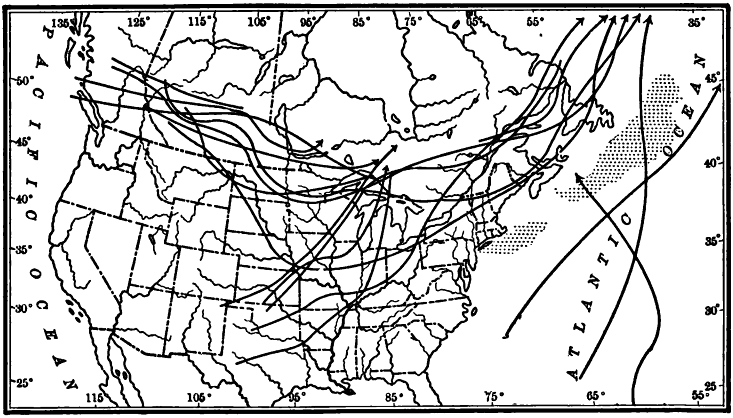


FIG. 416. — Paths followed by a number of low pressure areas during the month of November, 1891. The three in the ocean are hurricanes.

(B) *Anticyclones.* — West of the cyclonic storm (Fig. 414) is an area of high pressure (marked *High*), from which winds

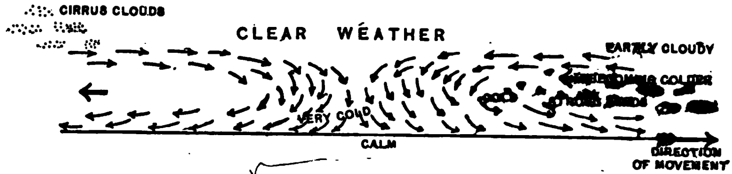


Fig. 417. — **Diagram showing theoretical circulation (by arrows), and other conditions, in a high pressure, or anticyclonic, area. Describe this diagram.**

blow outward in all directions, while the sky is clear and no rain falls. Such a high pressure area is often called an *anticyclone,* because in it conditions are the reverse of those in cyclones. Anticyclones move eastward as cyclonic storms do, even crossing the Atlantic.

Summary. — *Anticyclones are areas of high pressure with outward blowing winds and clear sky. They also move eastward.*

(C) *Succession of Cyclones and Anticyclones.* — Almost every weather map shows similar areas of high and low pressure (see Figs. 448–453). At intervals of from three to seven days, places in northern United States are liable to be visited, in fairly regular succession, by two low pressure areas with a high between (Fig. 418).

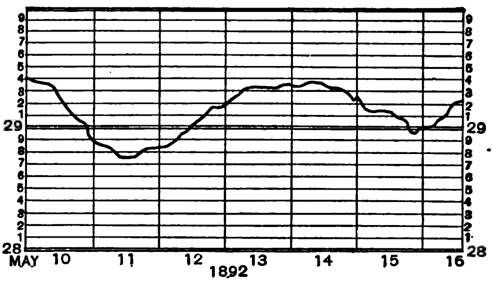


Fig. 418. — **Diagram showing change of pressure for seven successive days at Ithaca, N.Y. Figures in vertical column indicate inches and tenths of inches of mercury in the barometer. The two drops in the curve were caused by the passage of two low pressure areas.**

The passage of these areas is readily observed by watching the rising and falling of the barometer, or by observing the

weather. Cloudy weather, rain, and high temperatures usually accompany the lows, and clear, cool or cold weather, the highs; while the wind direction varies as these areas pass.

These high and low pressure areas follow several paths (Fig. 416). Most of them originate either in the northwest or southwest, but some reach the country from the Pacific. In either case, they move toward the east, usually crossing the Great Lakes region, going down the St. Lawrence, and then out to sea. The centers move 500 to 1000 miles a day.

Not all low pressure areas are true storms, for those in which the pressure is not very low have light winds and little, if any, rain. These poorly developed low pressure areas sometimes die out entirely; in other cases they rapidly develop into vigorous storms. It is such irregularities as these that make storm prediction uncertain; but, because they usually follow regular courses, most storms can be accurately predicted.

Fig. 419. — An eddy moving downstream, but with water whirling toward its center.

Summary. — *Cyclonic storms and anticyclones usually develop in the northwest or southwest, but often come from the Pacific, passing eastward across the country in fairly regular succession.*

(D) *Cause of Cyclonic Storms.* — Cyclonic storms are great eddies in the prevailing westerlies, and they occur both in the northern and southern hemispheres. They may be compared to the eddies in a river (Fig. 419), that move downstream with the current at the same time that water is whirling from all directions toward their centers.

In the same way, while the storm whirls are moving eastward with the prevailing westerlies, the air in them is eddying from all sides toward their centers.

Why these eddies develop is not certainly known. One theory is that they are started by the warming of air in some place, causing it to be light and therefore to rise, as air rises over a stove. Opposed to this theory is the fact that these storms are most common and best developed in winter, when heat is least likely to cause low pressure areas.

Another theory is that the highs and lows are air waves started in the westerlies. The regularity with which they come, their strength in winter when the west winds are best developed, and other facts, point to this as the more probable explanation. In either case, whether the air is warmed, or whether it is caused to rise and fall in waves, one part will have a lower pressure than another, and toward it air will flow, starting a whirl.

Summary. — *Cyclonic storms are eddies in the prevailing westerlies, with air whirling toward their centers from all sides. These eddies are low pressure areas, caused either by the warming of air or, more probably, by air waves started in the westerlies.*

(E) *Influence of Cyclones and Anticyclones on Weather.* — WINDS. (See also p. 289.) During the passage of high and low pressure areas the wind changes. On the east side of a storm the wind is from an easterly quarter, on the south side from the south, and between the cyclone and the anticyclone, from the west. The winds do not move along straight lines toward the center, but are turned by the effect of rotation so that they blow spirally; and if the differences in pressure are considerable, they blow with great force. Near the center the air rises (Fig. 412); but in an anticyclone it is steadily settling (Fig. 417).

TEMPERATURE. With these variations in wind direction the temperature also changes. Air from the south is warm, from the north, cool or cold. The settling air of the anticyclones brings to the earth some of the cool upper air. For

these reasons, when low pressure areas pass over a region there is usually hot, humid air in summer, and damp air and rising temperature in winter. But when the high pressure areas approach, the air becomes clear and cool in summer, and cold in winter. Radiation through the clear air of an anticyclone cools the ground far more than through the humid, cloudy air which mantles the earth during the passage of a low pressure area.

RAIN. When air is settling it is growing warmer, and, therefore, its vapor does not condense. Consequently anticyclones cause periods of dryness. In cyclonic storms, on the other hand, the rising air is becoming cooler, and its vapor is condensing, forming clouds and rain. The cloudy and rainy portions of a well-developed cyclonic storm may cover an area with a diameter of over 1000 miles.

There are two other important reasons for rain in these storms: (1) those winds which are blowing from the south are steadily advancing toward a cooler region; (2) in some places the air is forced to rise over highlands, like the Appalachians and New England. If, in either case, the air cools until it reaches the dew point, some of its vapor condenses.

In central and eastern United States the rain-bearing winds of cyclonic storms are mainly from the south and east. Winds from these quarters bear vapor from the ocean, and those from the south are, in addition, blowing toward cooler regions. In New England, well-developed cyclonic storms are commonly called *northeast storms,* because of the damp ocean winds then blowing from that quarter toward the center of low pressure.

When vapor condenses to form clouds and rain, the so-called "latent heat" (p. 238) is liberated, and this helps warm the air. It is partly for this reason that storms commonly increase in violence in passing over the Great Lakes and the ocean; for in these places more vapor is provided, and the heat from its condensation causes lower pressure and, therefore, a more rapid inflow and rising of air. A cyclonic storm has been called a great engine, furnishing some of its own energy as the vapor condenses.

Fig. 420. — Photograph of a tornado at Mt. Morris, Ill.

Fig. 421. — A waterspout off Marthas Vineyard, Mass.

FIG. 422. — Destruction done by the tornado at Mt. Morris (Fig. 420). In the roof of the upper figure, notice the laths driven through boards by the force of the wind.

FIG. 423. — Photograph of a distant thunder storm.

Summary. — *As high and low pressure areas pass, the winds vary in direction, the lows bringing warm air, clouds, and rain, the highs cool, clear air settling from aloft. The rain of cyclonic storms is caused (1) by the rising of air, (2) by its passage from warmer to cooler regions, and (3) by its rising over highlands. The heat liberated by condensing vapor causes the air to rise with increasing energy, and, therefore, over water storms increase in vigor.*

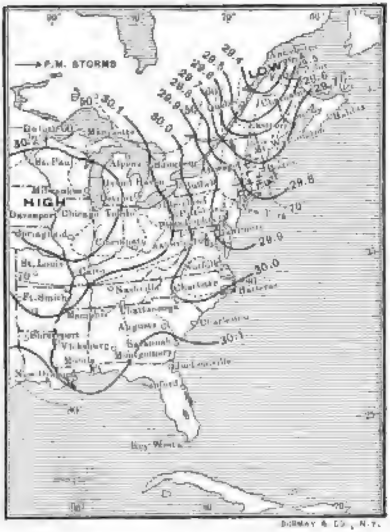


FIG. 424. — Part of a weather map, July 16, 1891, showing a low pressure area with thunder storms (indicated by arrows) in its southern part.

179. Thunder Storms and Tornadoes. — (A) *Thunder Storms.* — These are local storms which develop in low pressure areas, usually in the southern portion where warm, humid air is slowly moving from the south. On such muggy, oppressive days the air is not rising fast enough to form a blanket of clouds; but, as the ground is warmed during the day, the humid air rises, and patches

of cumulus clouds appear (p. 248). As the day passes these grow larger and darker, rising as masses of rolling, surging cloud, perhaps a full mile above the level base.

Rain finally falls from these clouds, and thunder and lightning are produced. The lightning is an electric spark, passing from cloud to cloud, or from the clouds to the earth, the electricity being produced when the air currents are swirling violently about and the vapor rapidly condensing. Thunder is the noise caused by the spark, and its rolling is the result of echoes among the clouds.

Thunder storms are often small, perhaps only a few hundred yards in area; but sometimes they are 50 to 100 miles long, 15 to 25 miles broad, and 3 to 5 miles high. They travel eastward in the west winds at the rate of 20 to 50 miles an hour, and may last from 2 to 10 hours before dying out. The rain is heavy, the winds often strong, and the lightning destructive. On the borders of thunder storms, hail frequently falls (p. 250).

Thunder storms occur in other places where warm, humid air is rising to a level at which its vapor rapidly condenses. For example, they are of almost daily occurrence in the belt of calms. Around mountains, too, as the air rises on a hot day, clouds often gather and develop into thunder storms. In arid lands these storms are sometimes accompanied by such rapid condensation of vapor and heavy rain that they are called "*cloudbursts.*"

Summary. — *Thunder storms are caused by the rising of warm, humid air in low pressure areas, usually in the southern portion; they are over-developed cumulus clouds. They also occur in the belt of calms, and where air is rising around mountains.*

(B) *Tornadoes.* — Tornadoes (Fig. 420) develop in the southern portion of low pressure areas under conditions similar to those causing thunder storms. The warm, humid, lower layers of air, brought by south winds, have above them cooler layers moving from the west. As the lower air warms and rises, a whirl starts around the center of rising, and the winds blow with great force. Like thunder storms, tornadoes often

occur in groups, perhaps a score or more developing at one time, and not very far apart. Heavy rain and hail fall at the margin of the whirl, and thunder and lightning occur.

The winds of the tornado whirl are so strong that houses are overturned, heavy bodies picked up and carried long distances, trees uprooted, and paths cut through the forest. In the center of the whirl there is a partial vacuum, and, as it passes, the air inside of houses expands with such force as to blow out the windows, and even the walls. The path of great destruction is only a few score yards wide, though it may reach a length of several miles before the tornado dies out. Although the passage of a tornado lasts but a minute or two, its work of destruction is so complete (Fig. 422) that tornadoes are much dreaded; and, in regions visited by them, holes, called "cyclone cellars," are made in the ground for shelter.

Fortunately tornadoes do not occur everywhere. They are especially abundant in the Mississippi valley. In that level, open country it is easily possible for warm, humid air from the Gulf of Mexico to slide in under the cooler, upper air and thus bring about the unstable conditions which are so favorable to tornado formation. They do not develop in arid countries, because the air is not humid enough; nor are they common in mountainous or hilly lands, because the irregular surface causes a mixture of warm and cool air layers. They rarely occur east of the northern Appalachians.

Summary. — *Warm, humid air, creeping under cooler layers in the southern part of low pressure areas, especially on the level plains, causes an unstable condition; and at times, as the air rises, the in-moving winds start a violent whirl, forming a tornado.*

(C) *Waterspouts.* — At sea conditions favoring tornadoes produce waterspouts (Fig. 421). In their center the water is raised in a low cone, and some salt water is actually carried up into the spout.

Summary. — *Waterspouts are tornadoes at sea.*

180. Hurricanes and Typhoons. — Very violent storms, known in the Pacific as *typhoons*, and in the Atlantic as *hurricanes*, develop in the tropical zone and move into the temper-

ate zones. On passing into the cooler temperate zones they become larger and less violent, and then closely resemble cyclonic storms. The path followed by the Atlantic hurricanes is usually across the West Indies, off the coast of the southern Atlantic States, then out to sea, curving eastward under the influence of the earth's rotation. Sometimes they depart from this course (Fig. 427), visiting the Gulf coast and even the Great Lakes. The typhoons of the Pacific and Indian oceans have various courses, some of those in the northern hemisphere passing over the Philippines.

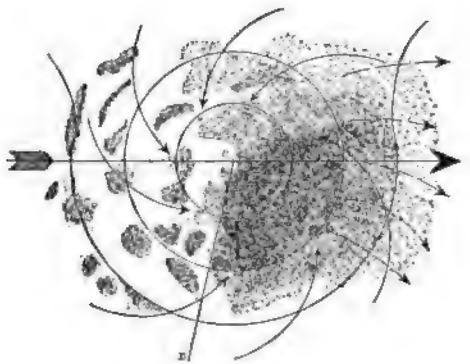


Fig. 425. — Diagram of a hurricane, showing direction of movement (long arrow), rain area (shaded), and winds eddying toward low pressure center, *C*.

These storms start by the rising of warm, humid air in the torrid belt, forming a whirl similar to that in a tornado, though much larger (Fig. 426). They originate on the ocean rather than on the land, because the humid air over the sea supplies much vapor, which, on condensing, liberates heat that warms the air and causes it to rise still more rapidly.

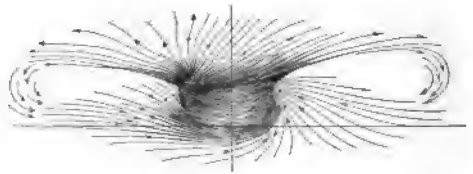


Fig. 426. — Graphic sketch to illustrate wind movement in a hurricane.

The pressure is very low in the center, though not approaching a vacuum. Toward this center violent winds

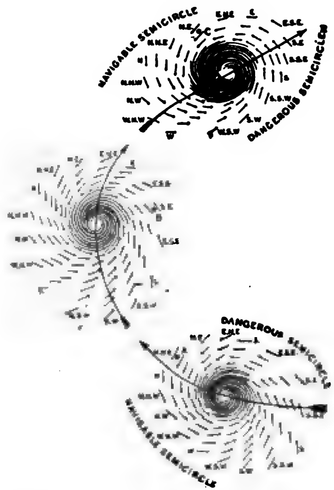


FIG. 428. — Diagram of spirally inflowing winds of a hurricane, together with the path pursued by the storm.

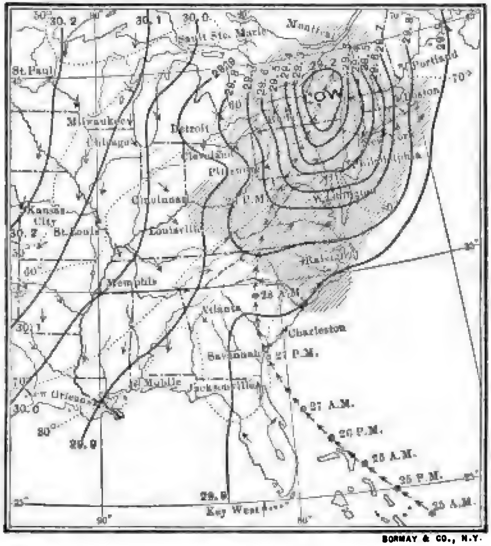


FIG. 427. — A hurricane, showing its path from the West Indies. It has gone a little out of the usual course (Fig. 416) and passed over the land. Rain area shaded.

FIG. 429. — A photograph in Galveston after the passage of the hurricane of 1900.

blow (Figs. 425–428), often with such force as to overturn trees and houses. Towns have been devastated and many vessels lost, as at Samoa in 1889, when several war ships were destroyed during a typhoon. Along the Atlantic coast of the United States the most violent storms are hurricanes, which often leave the coast strewn with wreckage.

Heavy rains, vivid lightning, and loud thunder accompany these storms. With them also travels a wave of high water, which, advancing on low coasts, causes much destruction, destroying houses, towns, and life. It was one of these waves, rising over Galveston, that, together with the winds, caused such terrible destruction in 1900, killing thousands of people and almost destroying the city (Fig. 429). Such a wave is due to two causes: (1) drifting of water toward the storm center by the spirally in-blowing winds (Figs. 425–428); (2) rising of water in the center because the weight of the air there is less than in the ring surrounding it.

Most hurricanes occur in late summer and early fall, because then the belt of greatest heat is farthest north. At the equator, winds are not turned by the influence of rotation; but, as the distance from the equator increases, they are turned more and more. Whirls can develop only when the winds are turned to one side so as to start a spiral movement around the center of rising. For this reason hurricanes cannot start at or near the equator; but they can start in the hot belt when it has migrated some distance from it. In the North Atlantic the period when the belt of calms is farthest from the equator is in late summer, and then hurricane whirls start in the rising air.

Summary. — *Hurricanes and typhoons are violent whirls, starting in the torrid zone, and resembling tornadoes, though larger and less violent. They start over the ocean because of the great amount of vapor, whose condensation supplies heat which causes more rapid rising. Their fierce winds, and the water wave which accompanies them, cause great destruction. They occur late in summer, or early in autumn, when the belt of calms is farthest from the equator, because then the effect of rotation can deflect the winds and start the spiral movement which causes the whirl.*

Topical Outline, Questions, and Suggestions.

Topical Outline. — 173. **Relation between Winds and Air Pressure.** — Air columns; effect of heat; low pressure; high pressure; cause of winds; barometric gradient; strong winds.

174. **Sea and Land Breezes.** — Cause of sea breezes; effects; land breezes.

175. **Mountain Valley Breezes.** — Movement down valleys; up valleys.

176. **Monsoon Winds.** — Place of best development; summer monsoon; winter monsoon; importance to sailing vessels; reason for lack of development elsewhere; condition in northeastern United States.

177. **Wind Systems of the Earth.** — (A) *Comparison with a Stove:* air movements in room heated by stove; on earth. (B) *Effect of Rotation:* right-hand deflection; left-hand deflection. (C) *Belt of Calms:* cause; doldrums; migration. (D) *Trade Winds:* steadiness; deflection; southeast trades; northeast trades; change in position; relation of Asiatic monsoons to trades. (E) *Antitrades:* upper outflow; direction; proof of existence. (F) *Prevailing Westerlies:* source of air; circumpolar whirl; effect of rotation; prevailing westerlies; interference with winds; westerlies over Southern Ocean; in northern hemisphere; high in the air. (G) *Horse Latitudes:* location; settling air; condition of winds; shifting of belts.

178. **Cyclonic Storms.** — (A) *Characteristics:* low pressure area; isobars; winds; rain; cyclonic storm; movement. (B) *Anticyclones:* pressure; winds; sky; name; movement. (C) *Succession of Cyclones and Anticyclones:* regular succession; weather changes; places of origin; paths; weak lows; irregularities. (D) *Cause of Cyclonic Storms:* comparison with river eddies; theory of heat origin; theory of wave origin; relation of eddies to low pressure. (E) *Influence of Cyclones and Anticyclones on Weather:* (*a*) Winds, — variation in direction; deflection; variation in force; rising air in lows; settling in highs. (*b*) Temperature, — south winds; north winds; settling air; passage of lows; of highs; radiation. (*c*) Rain, — reason for dryness in highs; effect of rising in lows; other causes for rain; source of vapor; northeast storms; effect of liberation of heat; storms over water.

179. **Thunder Storms and Tornadoes.** — (A) *Thunder Storms:* place of occurrence in low pressure areas; cause; growth; lightning; thunder; size; path; rate of movement; occurrence elsewhere; cloudbursts. (B) *Tornadoes:* favoring conditions; the whirl; comparison with thunder storms; effect of winds; condition in center; path; time of passage; cyclone cellars; occurrence in Mississippi valley; absence in other sections. (C) *Waterspouts.*

180. **Hurricanes and Typhoons.** — Typhoons; hurricanes; places of development; movement into temperate zones; paths followed; cause; reason for development over the sea; accompanying phenomena; effects of water wave; cause of wave; time of occurrence; explanation of this.

QUESTIONS. — 173. What is the cause of wind? What is barometric gradient? When are winds strong?

174. Explain sea breezes; land breezes.

175. Explain the day and night breezes of mountain valleys.

176. Where are monsoons best developed? Explain them. What is the condition in northeastern United States?

177. (A) Compare the circulation in a room heated by a stove with that of the earth. (B) In what direction, and why, are winds turned from a straight course? (C) What is the condition in the belt of calms? Why does it change position? (D) What are the directions of the trade winds? Why? What effect has the migration of the belt of calms? Why are the monsoons so well developed in Asia? (E) What is the direction of the antitrades? How is this known? (F) What is the circumpolar whirl? What is the direction of the winds? Why? What are the prevailing westerlies? What interferes with the regular winds? How do the westerlies of the northern and southern hemispheres differ? (G) What are the conditions in the horse latitudes? Why?

178. (A) What is a low pressure area? What are isobars? A cyclonic storm? State its characteristics. (B) What are anticyclones? Contrast with cyclonic storms. (C) What changes accompany the highs and lows? What paths are pursued? What irregularities are noticed? (D) Compare cyclonic storms with eddies in a river. State the two theories for these storms. What facts favor one rather than the other? (E) What is the nature of the winds in high and low pressure areas? What changes in temperature occur as these areas pass over a region? What are the causes of rain in the cyclonic storms? Why do storms commonly increase in violence when passing over large water bodies?

179. (A) Under what conditions do thunder storms appear in low pressure areas? Why? What is the lightning? The thunder? What are the characteristics of these storms? Where else do thunder storms occur? (B) Under what conditions do tornadoes develop? What are some results of tornadoes? Where are they most common? Why? In what situation are tornadoes rare? (C) What are waterspouts?

180. What are hurricanes? Typhoons? What paths do they follow? Why do they start over the sea? What destruction do they accomplish? Give instances. What destruction is done by the water wave? What is the cause of this wave? When are these storms most common? Why at that season?

SUGGESTIONS. — (1) Recall the previous experiments on convection (Chapter XII, 10). (2) Open a window on a cold day when no wind is blowing. Why does the cold air enter the room? (3) Keep a record of the wind direction for twenty days. How many days did the wind blow from each of the four quarters (north, east, south, and west)? For the same period keep a record of the direction that the higher clouds are moving. How many days do they move from each quarter? (4) On an outline map make a sketch of the winds of the globe similar to Fig. 408. Make a sketch to show the change in position of the belt of calms (Figs. 439, 440). (5) If the instruments are available, keep a record of the wind direction and force, humidity, temperature, clouds and rain, and barometric pressure (Appendix G). Tell when cyclonic storms and anticyclones are passing, and carefully record the relation between air pressure and the other phenomena. From your observations predict the weather for the following day. (6) Study weather maps (Appendix H). (7) With apparatus obtained from the physics laboratory make an electric spark. This is a lightning flash on a small scale, and the noise is thunder. A similar flash and noise may often be noticed as a trolley car passes. (8) If thunder storms occur, keep a record of all the phenomena and report upon them. (9) Read, say in *Harper's Weekly* for the autumn of 1900, an account of the destruction of Galveston. Be on the outlook next fall for newspaper reports of hurricanes or typhoons; also, next summer, for reports of tornadoes.

Reference Books. — HARRINGTON, *Rainfall and Snow of United States*, Bulletin C, U. S. Weather Bureau, Washington, D.C., 1894; FERREL, *Popular Treatise on the Wind*, Wiley & Sons, New York, 1889, $4.00; FINLEY, *Tornadoes*, Hine, New York, 1887, $1.00. (See also references at end of Chapter XII.)

CHAPTER XIV.

WEATHER AND CLIMATE.

181. Difference between Weather and Climate. — *Weather* refers to daily changes in temperature, wind, clouds, and rain. *Climate* is the average result of these weather changes. For example, certain parts of the tropical zone are said to have a rainy climate. This does not mean that it rains every day, but that, though the weather on some days is clear, on still more it is rainy. Thus the average condition, or the climate, is rainy.

The following are some of the more important kinds of climate: dry, hot desert climates; hot, rainy climates, as in the belt of calms; damp, equable ocean climates; extreme and variable climates, common in the interior of continents; and frigid climates. The greater part of the United States has a variable climate. These different climates, and the reasons for them, can best be understood by studying the conditions in various parts of the world.

Summary. — *Climate is the average of weather, which is the daily condition of temperature, wind, clouds, and rain. There are a number of very different climates on the earth.*

182. Zones of Heat. — (A) *The Five Zones.* — The most widespread cause for variations in climate is the distribution of sun's heat from equator to poles. This results from the difference in angle at which the sun's rays reach the earth in different latitudes (p. 239). From this has arisen the common division of the earth into five climatic zones, — two frigid, two temperate, and one torrid, or tropical (Fig. 430).

It is customary to draw the boundaries between these zones of heat along the parallels of latitude; but the actual boundaries are by no means so regular. Indeed, there are some portions of the torrid zone that have as low temperature as parts of the frigid zones; and some parts of the temperate zones have summer climates that are quite torrid. Several reasons for these irregularities are the following influences.

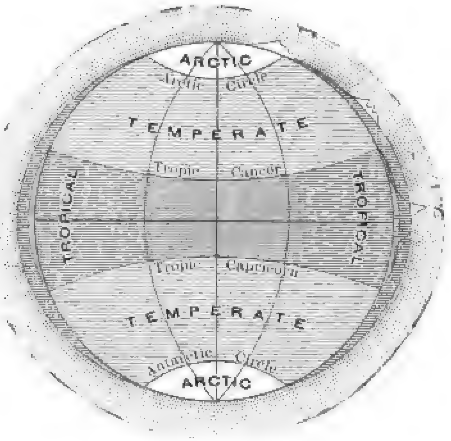


FIG. 430. — The five zones, showing, also, how on highlands a frigid climate may extend even into the tropical zone.

Summary. — *Owing to the angle at which the sun's rays reach different latitudes, the earth may be divided into five zones; but, for a number of reasons, the actual boundaries of the zones are irregular.*

(B) *Influence of Altitude.* — One important cause for irregularities in the boundaries of the heat zones is altitude. The climate of highlands is cooler than that of neighboring lowlands (p. 240). The isothermal charts[1] (Figs. 431–434) show numerous cases, as in the Rocky Mountains, where the isotherms are bent toward the equator in crossing highlands. The influence of altitude is also well shown along the Pacific

[1] An isotherm is a line connecting places having the *same average temperature.* An *isothermal chart* is one showing these isotherms for a given area (as the world, the United States, or a state) for a certain period of time. A chart for the year has isotherms passing through places whose average temperature for the year is the same; a chart for January averages all the temperatures for that period, etc.

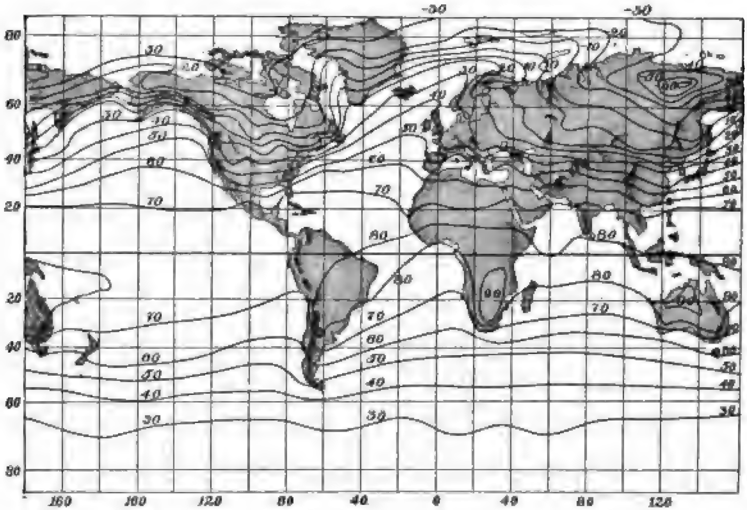


FIG. 431. — Isothermal chart of the world for January.

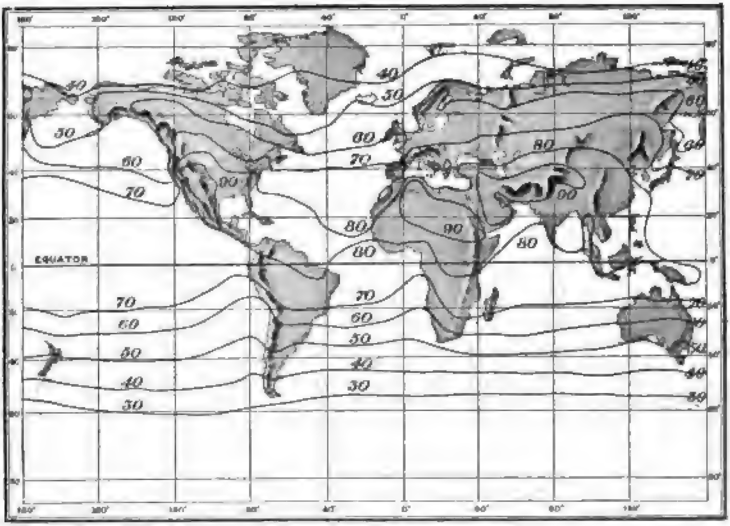


FIG. 432. — Isothermal chart of the world for July.

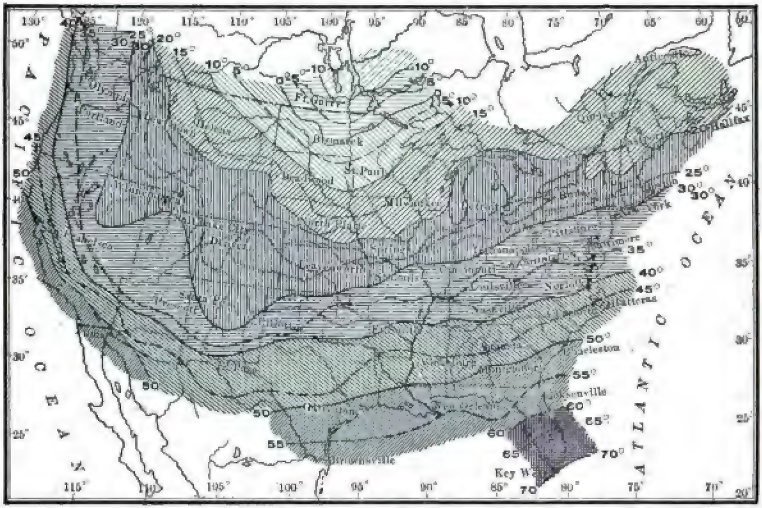


Fig. 433. — Isothermal chart of United States for January.

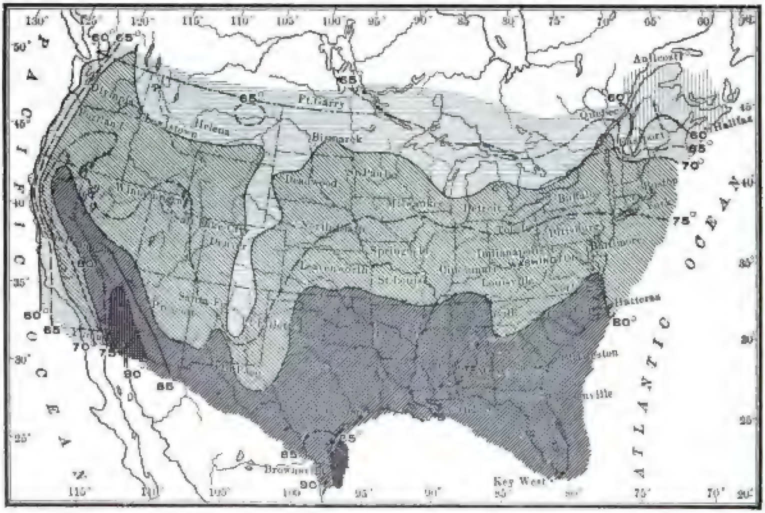


Fig. 434. — Isothermal chart of United States for July.

slope (Fig. 433), where winds from the equable ocean blow upon a rising coast, with mountains extending north and south. Along this coast the climate is warm and equable; but on the mountain slopes the temperature descends. Therefore the isotherms extend north and south instead of east and west, as is commonly the case.

Summary. — *Highlands are cooler than neighboring lowlands. Therefore highlands cause the isotherms, or lines connecting places having the same average temperature, to extend irregularly.*

(C) *Influence of Water.* — Distance from water (p. 238) is another cause for variation in temperature. Oceanic islands have cooler summers and warmer winters than the mainland in the same latitude; and seacoasts have more equable climates than interiors. This is clearly illustrated by comparing the isotherms in the interior and on coasts of continents.

Examine Figs. 433 and 434, for example, to see how much difference there is in January and July between Minnesota, the state of Washington, and Nova Scotia. Find other illustrations

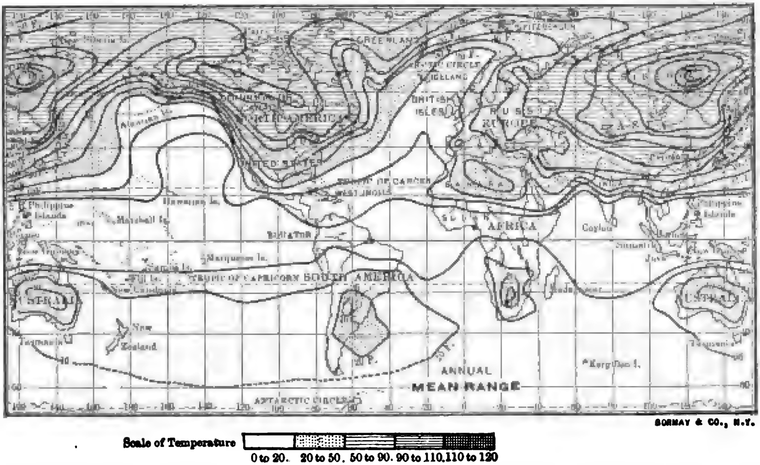


FIG. 435. — To show the annual mean (average) range in temperature for the world.

on the world charts (Figs. 431, 432). Study the chart of temperature range (Fig. 435) to see where there are great and small ranges. Contrast the range over the Atlantic with that over Asia and America; and the range over the Southern Ocean with that over the lands of the northern hemisphere.

Summary. — *Oceans and coasts have a far more equable climate than the interiors of continents.*

(D) *Influence of Winds.* — The influence of winds in causing irregularity in the isotherms is best illustrated, on a large scale, where winds blow from water upon land, as in northwestern United States and Europe (Figs. 431–434). In these places the prevailing west winds, influenced by the water over which they pass, moderate the cold of winter and the heat of summer. It is for this reason that in western Europe agriculture thrives, and large cities are found in latitudes that, in eastern North America, are frigid and almost uninhabited. London is in the same latitude as southern Labrador, and St. Petersburg as northern Labrador. For the same reason, the January temperature at San Francisco is the same as that at Charleston, S.C. (5° farther south), while the July isotherm is that of Halifax (6° farther north).

Summary. — *Prevailing winds influence the temperature, the most pronounced influence being where winds from the ocean prevail, thus carrying the equable temperatures of the water upon the land.*

(E) *Influence of Ocean Currents.* — Ocean currents and drifts bear water from one zone to another (p. 193). Winds blowing over these currents have their temperature influenced, and, blowing upon the lands, bear to them some of the warmth or cold brought by the currents from other zones.

This effect of ocean currents is well illustrated in the North Atlantic (Figs. 320, 431, 432). The great northward bend of the isotherms off the European coast shows the influence of the warm west wind drift (Fig. 338). This influence is least noticeable in summer when the sun has warmed the surface water. Off

northeastern North America, the cold Labrador current bends the isotherms toward the equator. Therefore, the isotherms are crowded together on the American coast and spread apart, fan-shaped, on the European coast. In other words, there are much greater differences in temperature in a short distance in eastern America than in western Europe. Notice also the influence of ocean currents on the isotherms along the west coasts of the United States, South America, and Africa.

Summary. — *Ocean currents warm or cool the air over them; moving as winds this air transfers the influence of the currents to the land. This is well illustrated in the North Atlantic.*

(F) *Influence of Topography.* — Hills and valleys have an effect of a local nature on climate. Mountains produce far more widespread effects. By shutting off winds, mountain barriers influence the climate of places behind them. Thus, while the Pacific slope of United States has an equable climate, the country farther east, being cut off from ocean winds by the mountains, has hotter summers and colder winters than the coast lands.

The subtropical climate of Italy, southern Spain, and France is partly due to the influence of topography. The waters of the Mediterranean are warm; the Alps and other mountains shut out the cold north winds; and they interfere with south winds which might bear away warmth from the Mediterranean. Therefore, in this region, oranges and palms grow (Fig. 443) in the latitude of Boston, New York, and other places in the United States which are visited by killing frosts for several months of the year.

Summary. — *Hills and valleys have a local influence on climate, and mountains far greater effects, especially in shutting out winds.*

CLIMATIC BELTS OF THE TORRID ZONE.

183. Belt of Calms (Fig. 408). — The vertical position of the sun in the equatorial belt of calms (p. 259) causes the climate to be hot (p. 240). This belt is also a very rainy

one (Figs. 436–440, 444), because the rising air soon reaches an elevation where its vapor condenses (p. 268).

The weather of the belt of calms is monotonously uniform. On the ocean, or on oceanic islands, the air grows warmer each day after the sun rises; and from the clouds which form, and which often develop into violent thunder storms, heavy rain falls. During the night the humid air is still warm, for there is not enough radiation to cool it. Both day and night there is an absence of steady winds, and sailing vessels are often becalmed for days. These conditions are repeated with marked regularity. The daytime temperatures are higher on the land, and winds are often caused by differences in temperature, for example, along the coast where sea breezes blow (p. 256).

Fig. 436. — Rainfall of calm and trade-wind belts of America.

The rainfall is so heavy that dense forests thrive on the land, and the air within these is reeking with moisture. So warm and damp is the climate that it is difficult to work; the clearing away of vegetation for planting is such a task that it is rarely undertaken; and, in fact, there is little need for doing so, since, with little labor, the forest plants yield abundant food. For these reasons the tropical forest is inhabited by races depending directly upon nature for food, who, having little ambition for improving their condition, have made little progress toward civilization.

Summary. — *The belt of calms has a hot, humid climate with a general absence of winds. The heat and humidity cause a rank growth of tropical forest, but discourage progress among mankind.*

184. Rainy Trade-wind Belts. — To the north and south of

the belt of calms the trade winds (p. 259) blow toward warmer regions. Vapor is therefore constantly rising into them, because, the warmer the air, the more vapor possible (p. 244). So much fresh water is thus removed that the sea is made more salt (p. 181) where the trade winds blow. These winds bear such quantities of vapor that, when they blow over rising land, where the air rises and cools, vapor is condensed. East-facing coasts, against which the trade winds blow, are, therefore, very rainy (Figs. 436–440, 444).

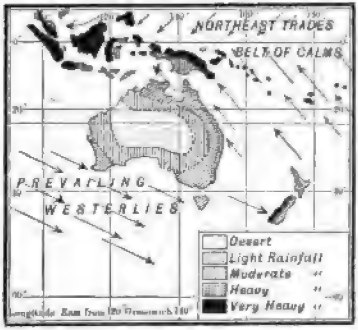


Fig. 437. — Rainfall of calm, trade-wind, and westerly belts of Australasia.

The east coast of South America, both north and south of the equator (Fig. 436), the East and West Indies, northeastern Australia (Fig. 437), and southeastern Africa (Fig. 438) have heavy rains, because the trade winds blow upon them from the sea. These places have a tropical forest, resembling that of the belt of calms. Mountainous oceanic islands in the trade-wind belt, like the Hawaiian Islands, have heavy rains on the eastern or windward side while the opposite side has a dry climate.

Summary. — *East-facing coasts in the trade-wind belts have a rainy climate, because, as the damp air cools in rising over the land, some of the vapor, evaporated from the ocean, is precipitated.*

185. Desert Trade-wind Belts. — In the trade-wind belts arid conditions are far more common than rainy; in fact, the trade winds furnish the most important cause for deserts. They take up vapor in passing over the land for the same reason as on the ocean; but there is so little moisture to be obtained on land that they become very dry winds, into which

vapor rises wherever possible. This leaves so little water for plants that the land is made desert; but even in the driest desert air there is some vapor, and rain occasionally falls. In the Mohave desert of Arizona the rainfall is less than two inches a year.

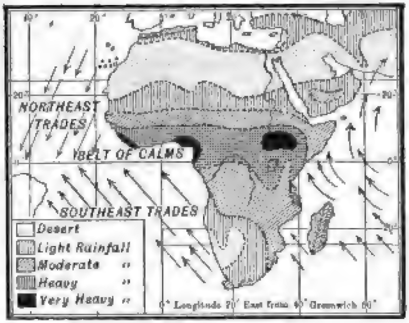


Fig. 438.—Rainfall of calm and trade-wind belts of Africa.

Because of these conditions both north and south of the equator, there is a broad belt of arid and desert country extending almost completely across the continents, though on east-facing coasts interrupted by rainy belts. These desert belts include parts of Australia (Fig. 437), South Africa (Fig. 438), southern South America (Fig. 436), and southwestern United States (Fig. 442); but the largest desert tract is in the great land area of northern Africa and Asia. Commencing in western Africa, there is a series of deserts extending far toward the east coast of Asia (Fig. 444). The great Sahara is a part of this belt.

In many places the deserts of the trade-wind belts merge into the arid regions of the horse latitudes (p. 261). Here also the air is warming, and evaporation, therefore, proceeds rapidly.

Life in the deserts presents a far different picture from that in the tropical forest. Only a few species of plants are adapted to life amid the unfavorable conditions, and even these are scattered (p. 342). Therefore, the desert is a barren, open country; and neither animals (p. 357) nor men (p. 386) find it a favorable place for a home. Deserts are among the most sparsely settled parts of the world.

The weather is nearly always dry, the sky usually cloudless, and the winds often strong, blowing sand about (p. 87). Even in the temperate zone the days are warm, and in summer hot. For example, in the desert of southern Arizona, though far north

of the tropic of Cancer, the thermometer sometimes rises to 120° in the shade. The highest air temperature recorded (127°) was in the Algerian desert. But radiation is rapid in the dry desert air, and at night the ground and air cool so quickly that a blanket may be necessary before morning.

Summary. — *Where air is growing warmer, as in the trade-wind and horse-latitude belts, the climate is dry and the land arid or desert. Most of the deserts are in these belts. Deserts are unfavorable to life, — plant, animal, and human. The desert climate is dry, often windy, and hot days are followed by cool nights.*

186. Savanna Belts. — Between the rainy belt of calms and the trade-wind deserts there is, in each hemisphere, a region, called the *savanna* belt, that has alternate dry and wet seasons. This peculiar climate is caused by the migration of the belt of calms (p. 259). In the hot season the belt of calms migrates to the savannas and there is heavy rain (Figs. 439, 440); but in the opposite season the savannas are under the influence of the drying trade winds.

As a result of these changes, the hot season (the time of our summer in the northern hemisphere, and of our winter in the southern) has copious rainfall, and vegetation freshens and grows vigorously; but in the opposite season the ground is parched, and vegetation withers. The season of drought is too severe for many forms of vegetation, such as trees. Therefore, the savannas are covered with those plants, such as grass (Fig. 491), which are able to survive a period of drought (p. 342).

The *downes* of Australia, the *park lands* of Africa, the *llanos* of Venezuela and Colombia, and the *campos* of Brazil are examples of savannas. Their grass supports large numbers of plant-eating animals, upon which flesh-eating mammals prey.

Savannas are probably destined to become the most productive and best-settled lands in the tropical zone. The open country favors agriculture, and the drought makes necessary some provision for that season. Being thus forced to industry and thrift, the negroes of the savannas have become farmers and cattle raisers, and are the most advanced blacks of Africa.

Summary. — *The migration of the belt of calms brings abundant rain to the margin of the desert trade-wind belt during the hot season, giving rise to alternate seasons of drought and rain. This makes such regions, called savannas, great pasture lands, well adapted to life.*

187. The Indian Climate. — As a result of the influence of the monsoons (p. 256), parts of India have a peculiar climate with three well-defined seasons, — the hot season, the rains, and the cool winter. During the hot season, which lasts from April to June, hot, dry winds from the land cause the temperature to rise above 100° in the shade. In June the air becomes calm and the heat almost suffocating, and every one longs for the summer monsoon. When this begins, clouds appear, rain falls, and for a month or two rains are of almost daily occurrence, causing vegetation to grow profusely.

A short period of calm follows the summer monsoon, and again the heat is intense; but cool air from the interior soon begins to flow down toward the sea, and by October the winter monsoon is established. The air is then clear and cool, and by January, in many parts of India, fires are necessary. In February and March a sort of spring visits the land. Vegetation then bursts forth, only to be withered by the scorching drought of the hot season, which postpones the real growing season until the summer rains.

So heavy is the rainfall on the mountain slopes that, in places, the soil is completely washed away. The heaviest rainfall in the world is at the base of the Himalayas (Fig. 441). In a year there are about 500 inches of rain; that is, if it should all stand where it fell, it would form a layer of 40 feet. Of this amount about two thirds falls in the five summer months. On a single day there have been 40 inches of rain, or more than falls in most parts of the United States in a year.

Summary. — *The Indian climate consists of a hot season (April to June); a rainy season, during the summer monsoon (June to August); and a cool season, during the winter monsoon. In parts of India the rainfall during the summer monsoon is very heavy, the rainiest part of the world being in northern India.*

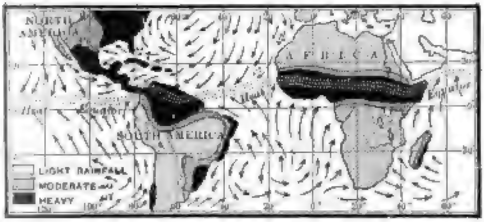
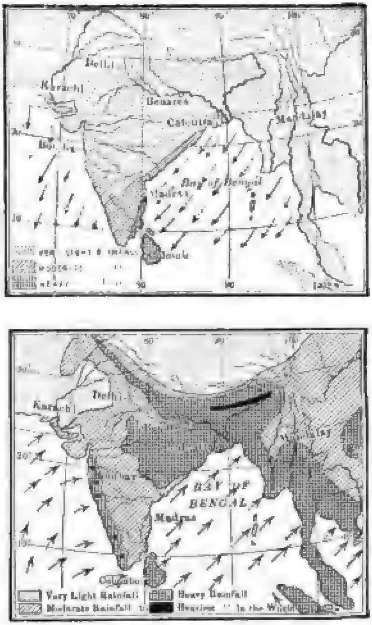


Fig. 439.—Sketch map of winds and rainfall in summer. Zone of greatest heat marked by dots, an imaginary line in the center of this area being the *heat equator*.



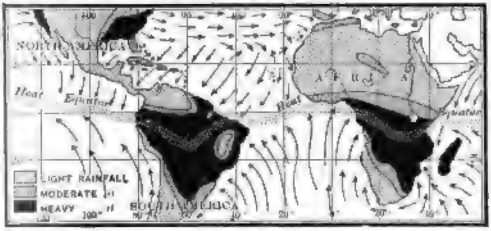


Fig. 440.—Sketch map of winds and rainfall in winter. Compare with Fig. 439 to see nature and effect of migration of wind belts.

Fig. 441.—Summer and winter rainfall of India, the difference resulting from the monsoons.

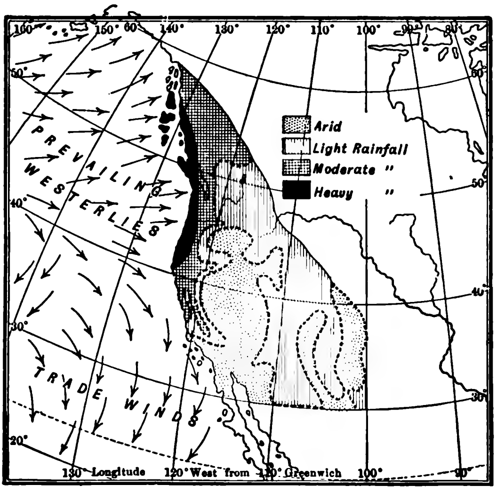


Fig. 442.—Rainfall of northwestern North America.

Fig. 443. — Subtropical flora of southern France, at Nice, in the same latitude as Portland, Maine.

CLIMATES OF THE TEMPERATE ZONES.

188. Variation (in Temperate Zones) from North to South. — (A) *Temperature.* — The temperature varies greatly from near the tropics toward the poles; but, excepting near the tropics, there is everywhere a decided difference between summer and winter. Near the polar circles the summers are so cool, and the winters so cold, that the climate is often called subarctic. No trees grow there (p. 340); no agriculture is possible; and there are almost no human inhabitants, excepting along the seacoast, or in mining camps, like the Klondike.

These treeless tundras merge into a forest belt, and vegetation becomes more and more luxuriant until, near the tropics, the climate is so warm that it is called subtropical. In this warm belt cotton, sugar, oranges, and even bananas, pineapples, and cocoanuts are grown.

Summary. — *The climate of the temperate zones changes from cold, or subarctic, near the polar circles to hot, or subtropical, near the tropics; and with these changes there are variations in vegetation from treeless tundra to subtropical forest.*

(B) *Rainfall.* — The rainfall also varies from north to south. Most temperate regions have a moderate rainfall, decreasing toward the frigid zone and also toward the tropics. The rainfall decreases toward the frigid zone, because there can be less vapor in cold than in warm air (p. 245). It decreases toward the tropical zone because the horse latitudes are naturally arid regions (p. 282).

The arid horse-latitude belts, in which are included southern California, southern Texas, Spain, Italy, Greece, and the steppes of Russia, grade in one direction into the deserts of the trade-wind belts, and, in the other, into the damp climate of the mid-temperate zone. They may be called the belts of *steppes.* Some parts of the horse-latitude belts, like Florida, have abundant rain-

fall, because exceptional conditions cause winds to blow from the ocean. Some parts, on the other hand, are true desert.

Steppes are dry in summer; but some sections are reached by the west winds when they migrate southward in winter, bringing snow and rain. Therefore irrigation is necessary for agriculture, as in Italy, which has dry summers and rainy winters. Where best developed, steppes are too dry for trees; but grass grows in spring, curing to a natural hay during the warm, dry summer, thus serving as a food for cattle.

Summary. — *The rainfall decreases toward the north because the air is cool; in most places it also decreases toward the south, and, in the horse-latitude belts, there are regions of arid steppes.*

(C) *Effect of Mountains.* — While in southern Europe (p. 279) subtropical plants grow in the latitude of the New England and Middle Atlantic States, in our country such plants do not thrive, even in northern Florida. There are no lofty mountains to prevent cold north winds from sweeping down to the Gulf. Therefore cold waves reach as far as New Orleans and northern Florida, causing such destructive frosts that it has been necessary to give up orange culture in northern Florida. In one respect these cold winds are an advantage, for they are invigorating, and the people of the South do not suffer, as some warm temperate peoples do, from the enervating effects of too much warmth.

Summary. — *The absence of east-west mountain chains makes it possible for cold waves to reach even to the Gulf.*

189. Variation (in Temperate Zones) from West to East. — Owing to the fact that the prevailing winds of the temperate zones are from the west, there are decided differences in climate from west to east.

(A) *West Coasts.* — The warm, damp winds that blow from the ocean upon west-facing coasts cause a humid, equable climate. This is well illustrated on the northwest coast of the United States and Europe (pp. 278 and 279). While in eastern United States droughts often cause the grass to become parched, the dampness of the air in the British

Isles keeps it green. Hence the name Emerald Isle for Ireland.

The heaviest rainfall in the United States is on the northwest coast (Figs. 442, 445), where damp air from the ocean rises up the mountain slopes. There the rainfall amounts to 100 inches a year; and in winter, when the land is cool, and the westerlies most steady, there is rain, drizzle, or fog almost daily. For the same reason there is heavy rainfall on the southwestern coast of Chile (Fig. 444). But in the horse-latitude and trade-wind belts, as in southern California and northern Chile, the climate, even on the seashore, is arid.

Summary. — *On west coasts of the temperate zone, where reached by the prevailing west winds, the climate is damp and equable. The heaviest rainfall in the United States is on the northwest coast.*

(B) *Effect of North-south Mountains.* — Along the west coast of Europe there is especially heavy rainfall on the mountain slopes, as in Wales, Scotland, and Norway. But, since these mountains are not very high or continuous, its winds are able to carry vapor far inland, even into Asia. Because of this fact Europe, north of the horse-latitude belt, is well watered and the seat of extensive agriculture.

In western North America, on the other hand, as the air rises over the high, continuous mountains, so much of its vapor is condensed that it descends on their eastward slopes as dry air. Accordingly, from the Sierra Nevada-Cascade ranges eastward to the 100th meridian — the part of North America which corresponds in position to Germany, Austria, and eastern Russia — most of the country is arid; and even farther east, in the Mississippi valley, there are frequent and destructive droughts.

Summary. — *Western United States differs from Europe in the greater influence of its higher, more continuous mountains, which cause the winds that cross them to reach the other side dry, forming arid regions as far east as the 100th meridian.*

(C) *Interior of Continents.* — The interior of a continent, being far from the sea, receives much less rainfall than a windward coast. Thus there are frequent periods of drought in central western Asia and in central United States. These droughts are less destructive in the northern part, because in a cool climate lighter rainfall suffices for crops. There are two reasons for this: (1) in cool climates the slight evaporation allows the dampness to remain long in the ground; (2) melting frost keeps the soil damp for a long time.

One striking peculiarity of the interior of continents is the great range of temperature between the warm or hot summers and the very cold winters (Figs. 431–435). During the summer day the temperature may rise above 100° — truly tropical heat; and in winter it may descend to the Arctic cold of even 40° below zero, giving a range of perhaps 140° in a single year. Minnesota and neighboring states illustrate this extreme, or *continental climate.* It is also illustrated in central northern Siberia, near the Arctic circle, where moderately warm summers are followed by bitterly cold winters. In fact, this is the coldest known place (Figs. 431, 435), and has been called the *cold pole* of the earth.

It is distance from the sea, and freedom from its influence, that account for the extreme climate of the interior of continents. The land warms in summer, when the sun, though low in the heavens, stays long above the horizon. In winter, on the other hand, the nights are very long, and during the short days the sun is low in the heavens. Under these conditions radiation is far in excess of the heat supplied, and the land becomes exceedingly cold.

Summary. — *Interiors of continents, being far from the sea, are liable to drought; and there is great range in temperature, from warm or hot summers to cold winters. This is known as a continental climate.*

(D) *East Coasts.* — Since the prevailing westerlies must cross the continent before reaching east coasts, one might expect to find arid climates there. Aridity is prevented,

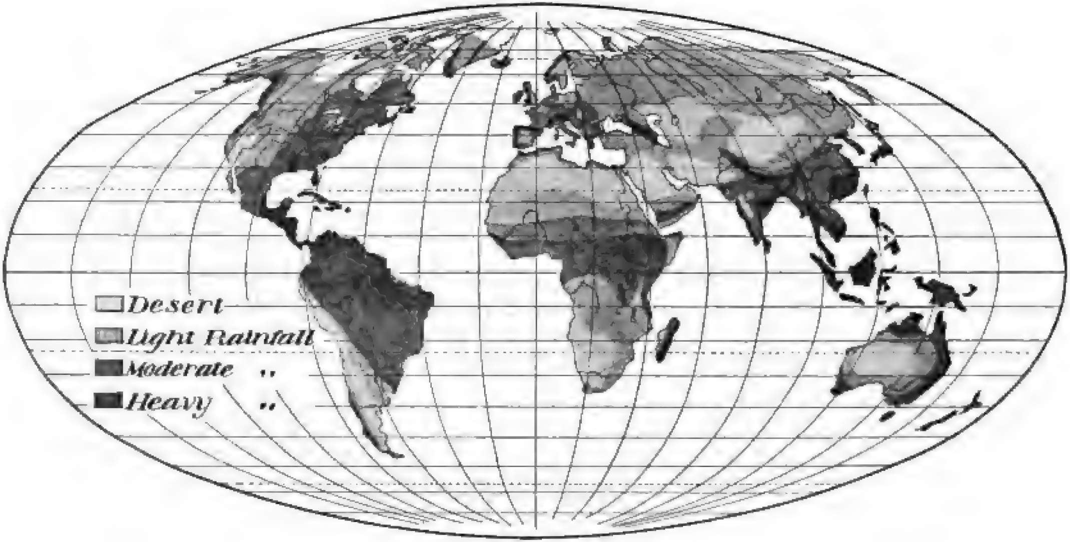


Fig. 444. — Rainfall map of the world.

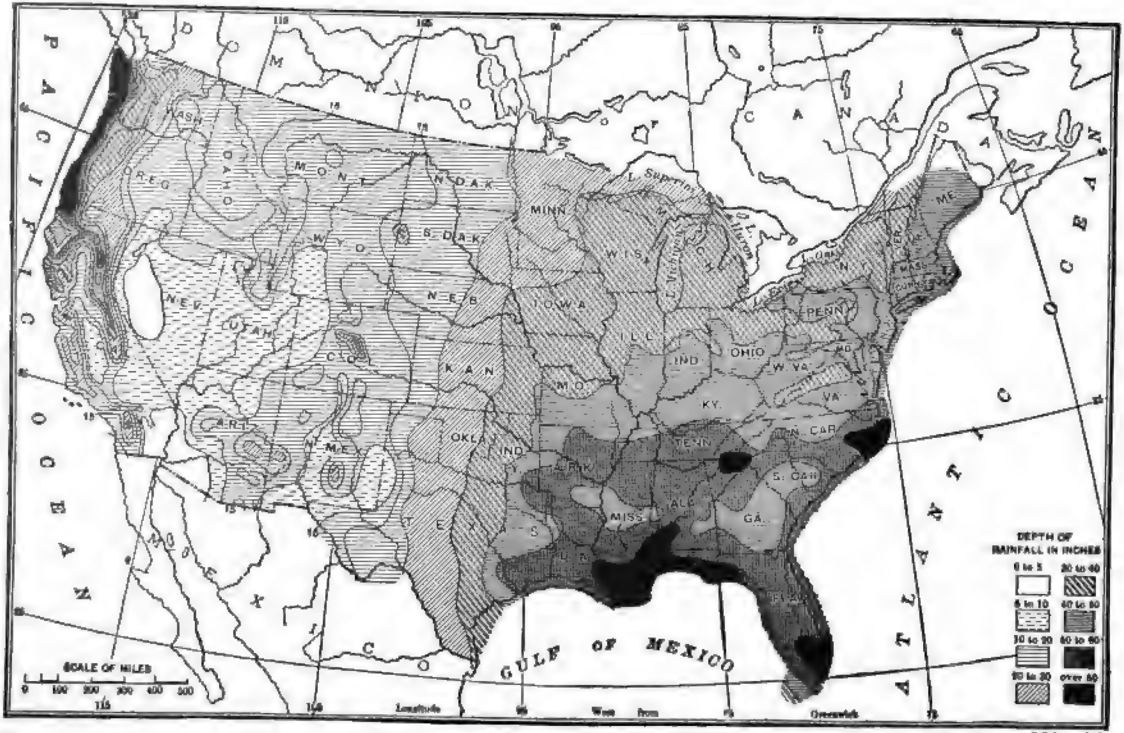


FIG. 445. — Rainfall chart of the United States.

however, by the winds of the cyclonic storm eddies (p. 262), which frequently replace the west winds. Some of these winds blow from the Atlantic or Gulf of Mexico, bringing the vapor which gives eastern United States its abundant rainfall.

Because of the influence of cyclonic storms, the climate of east coasts is variable. The west winds are dry and cool in summer, and dry and cold in winter; but whenever storm winds blow from the sea, both the temperature and humidity are influenced by the ocean. Thus in northeastern United States the east winds are damp and chilly, being cooled in passing over the Labrador current; and in summer they often bring fogs. The south winds, warmed in passing over the Gulf Stream or the Gulf of Mexico, are warm and damp. From day to day the weather varies (p. 265), one day being like the interior of continents, another like the equable ocean.

Summary. — *The cyclonic storm eddies of the west-wind belts give east coasts a very variable climate, with rain when winds bring abundant vapor from the sea.*

190. Variable Winds of the Prevailing Westerlies. — Among the winds caused by the passage of cyclonic storms and anticyclones (p. 265) are some so distinctive that they deserve special names. The gentle south wind, which causes oppressively warm weather in summer, and unseasonable warmth in winter, may be called the *sirocco.* It is when the sirocco blows that thunder storms and tornadoes develop in summer, and thaws occur in winter.

Of the very opposite type are the west and northwest winds that sometimes blow on the rear of vigorous winter cyclones. These cold winds, often filled with snow, are called *blizzards* in Dakota and *northers* in Texas. Because of the marked difference in the barometric gradient (p. 255) between the cyclone and the anticyclone the air moves with great velocity, perhaps 40 to 60 miles an hour. The cold, and the fierce snow squalls, often cause destruction of life among sheep and cattle; even men are sometimes lost in the blinding snow, and frozen by the fierce cold. Milder forms of blizzard occur in northeastern United States.

A *cold wave* (Fig. 446) is a rapid drop in temperature during the passage of a well-developed anticyclone (p. 263). At such times a wave of cold air spreads over a large part of the country, even down to the Gulf (p. 286). This blanket of air descends from the cold northern interior and from aloft (Fig. 417); and since it is, therefore, warming as it spreads out, it is clear and dry. Through it radiation proceeds readily, causing very low temperatures in winter, refreshingly cool weather in summer, and early and late frosts in fall and spring (p. 246). The term cold wave, however, is commonly applied only to the winter condition.

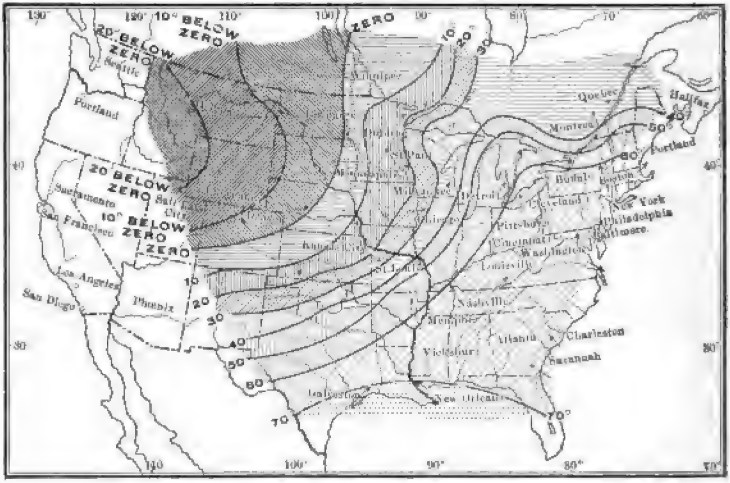


Fig. 446. — A cold wave, spreading outward from an area of high pressure in the northwest, November 27, 1896. Arrows show outward movement of the air.

The passage of cyclonic storms sometimes causes an exceedingly warm, dry wind, known as the *foehn* in the Alps and the *chinook* in the Rocky Mountains. These winds are caused by the rapid passage of air across mountains toward a storm center. As the air rises on one side it loses much of its vapor, descending as dry air on the opposite side. It descends so rapidly that it is warmed by compression, as the air in a bicycle pump is warmed

(p. 241). This warming lowers the relative humidity (p. 244) until the air becomes very dry; in fact, the Swiss formerly believed that the foehn came from the Sahara. In the warm, dry air, snow disappears rapidly, and houses become so dry that fires are greatly feared. Whole villages in Switzerland have been wiped out by fire during the foehn winds.

Summary. — *A sirocco is a warm, gentle south wind blowing toward a cyclonic storm; a blizzard, or norther, is a fierce, cold wind, with squalls of snow, in the area between well-defined cyclones and anticyclones; a cold wave is the outspreading blanket of cold air in an anticyclone; the foehn, or chinook, is a warm, dry mountain wind made warm and dry by rapidly descending the mountain slopes in its passage toward a low pressure area.*

191. Weather of Eastern United States. — (A) *Summer Weather.* — The typical summer weather of eastern United States may be illustrated by the following actual instance. A cool, dry, gentle west wind is accompanied by a day of agreeable warmth, a night of refreshing coolness, and a nearly cloudless sky. An anticyclone is passing over the region, and following it is an area of moderately low pressure. As this approaches, the wind veers to the southeast, the temperature rises, the air becomes more humid, and both day and night are muggy and oppressive. On the morning of the second day, clouds fleck the sky, in the afternoon growing to thunder-heads. About four o'clock a thunder storm appears, preceded by a fierce squall; then comes heavy rain, accompanied by vivid lightning and crashing thunder. After the storm, a west wind blows and, as another anticyclone passes, the air is again dry and refreshing.

This cycle is repeated with some regularity, though there are numerous variations. At times the low pressure areas are so poorly developed that for several weeks little rain falls. There is then a drought, during which streams and wells run dry, vegetation withers, and crops suffer. At other times a low pressure area is so well developed that, instead of scattered thunder storms,

there is general cloudiness and rain. This is especially true in late summer and early autumn, when hurricanes accompanied by strong winds and heavy rains pass up the coast.

Summary. — *Summer weather in eastern United States is variable, being warm and oppressive, often with thunderstorms, when south winds blow toward moderately developed areas of low pressure, and cool and refreshing when anticyclones pass.*

(B) *Winter Weather* (Figs. 446–453). — Both cyclones and anticyclones are much better developed in winter than in summer. They pass over the country in fairly regular succession (p. 263), bringing alternate clear and cloudy weather. Their appearance is sometimes so regular that one day of the week has nearly the same kind of weather for several successive weeks.

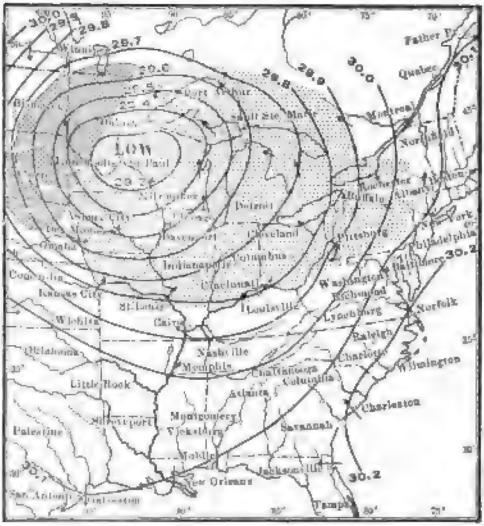


FIG. 447. — A winter storm, showing winds blowing toward Low, and the large area over which rain (dotted) and snow (cross-lined) are falling.

During the passage of cyclones, there may be rain, or snow, or both. The wind varies in velocity (p. 265) and veers through various quarters, bringing chilly air from the north or east, warm air from the south. While the south wind is blowing a thaw may set in, and, even in midwinter, rain may fall as far north as Canada. A thaw is often followed by a decided drop in temperature as the next anticyclone approaches.

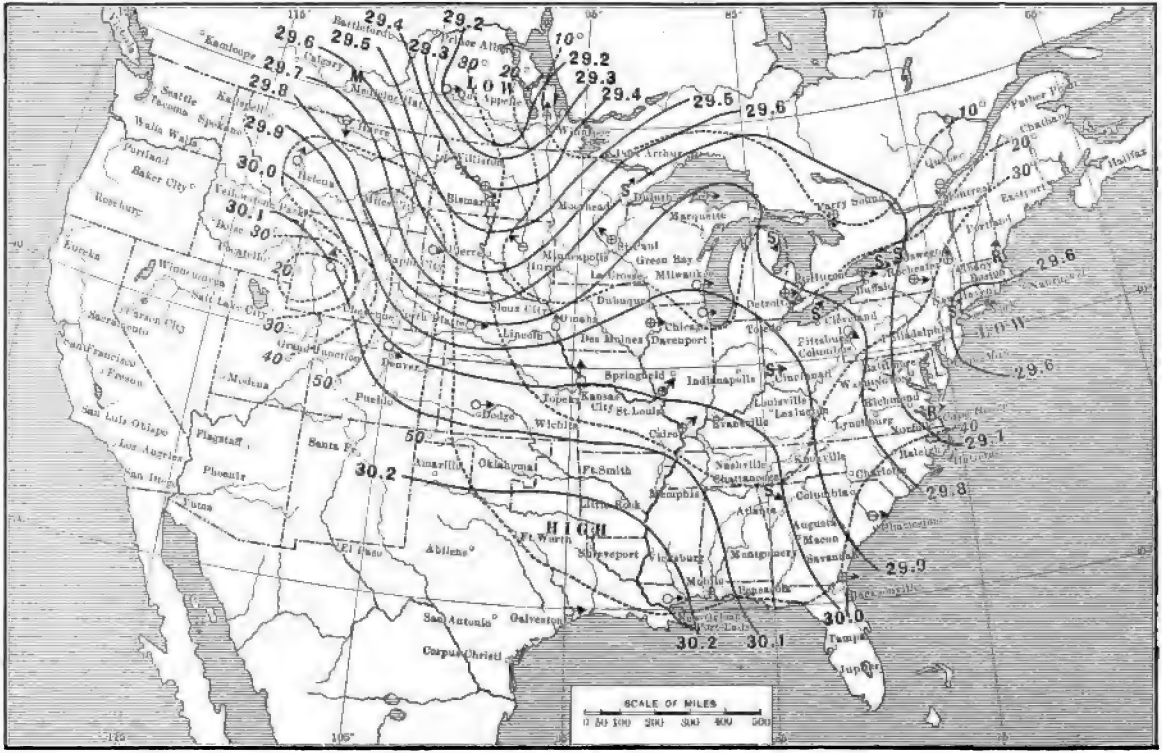


FIG. 448. — Weather map, January 6, 1903, showing a low pressure area in the Northwest. The heavy lines (isobars) show barometric pressure (29.2 being the number of inches the air pushes the mercury into the tube of the barometer). The dotted lines (isotherms) pass through places with equal temperature. The arrows point in the direction the wind is blowing. A plain circle O means clear weather; ⊖ partly cloudy; ⊕ cloudy; R rain; S snow.

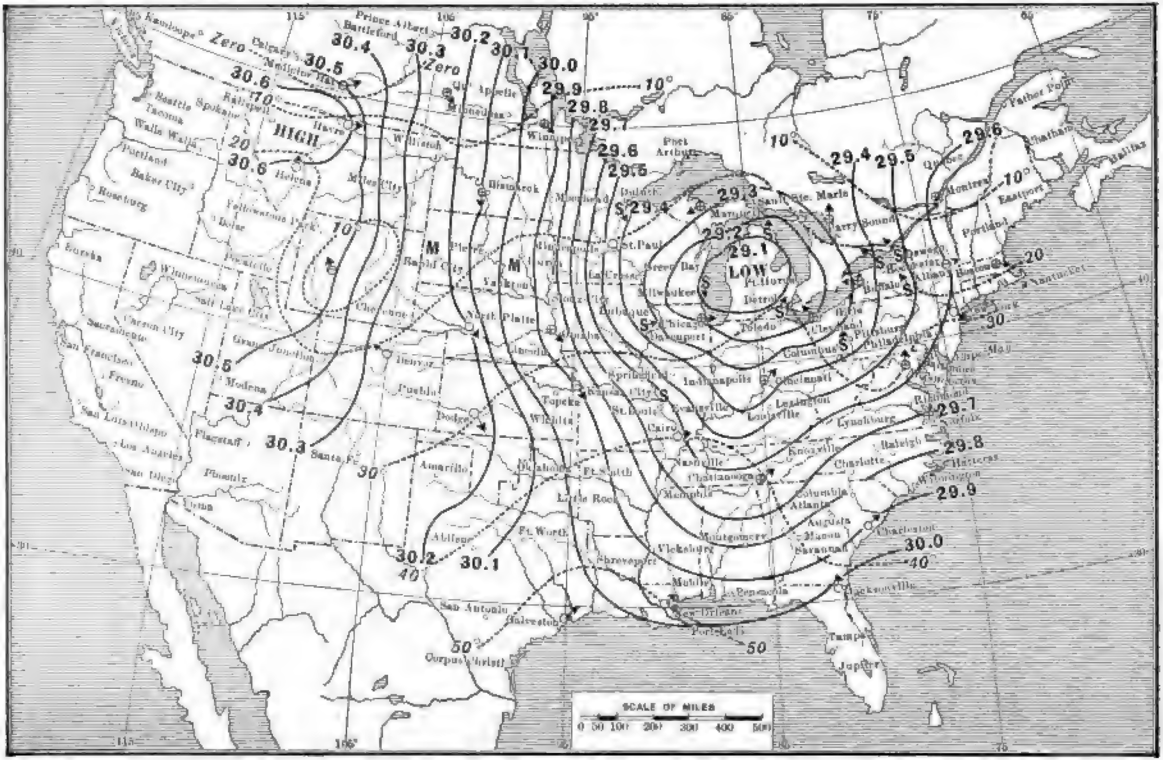


Fig. 449. — Weather map, January 7, 1903, showing the storm (Fig. 448) moved eastward, and a High appearing in the West. Symbols same as Fig. 448.

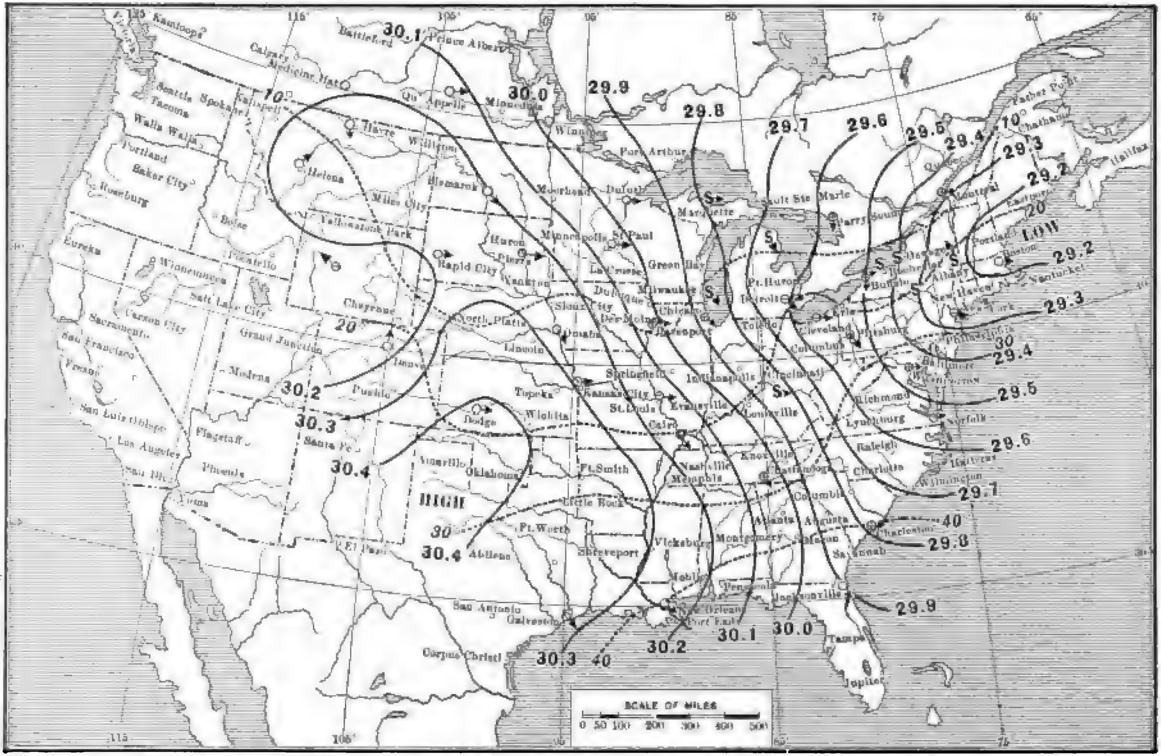


Fig. 450. — Weather map, January 8, 1903, showing the storm (Fig. 448) just leaving the coast. Symbols same as Fig. 448. Describe the changes in pressure, temperature, and wind direction accompanying the passage of this storm. (Figs. 448, 449, 450.)

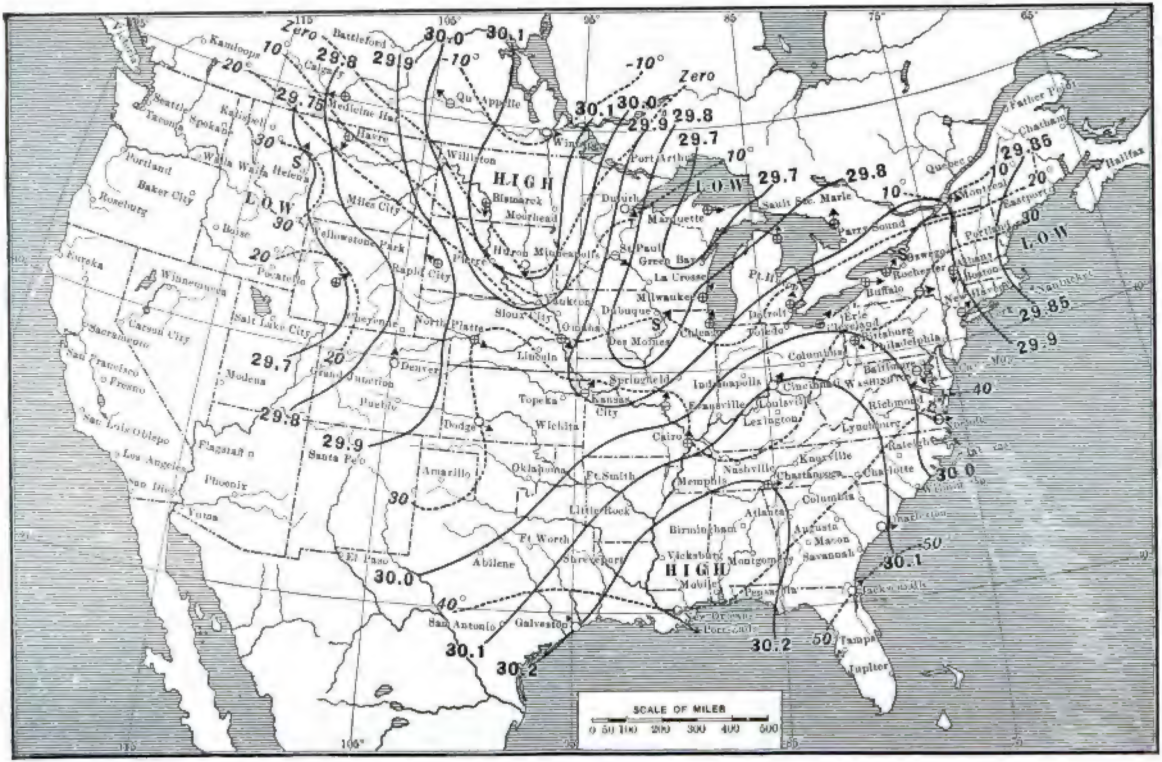


FIG. 451. — Weather conditions, January 22, 1903, showing a high pressure area in the West. Symbols same as Fig. 448.

FIG. 451. — Weather conditions, January 22, 1903, showing a high pressure area in the West.

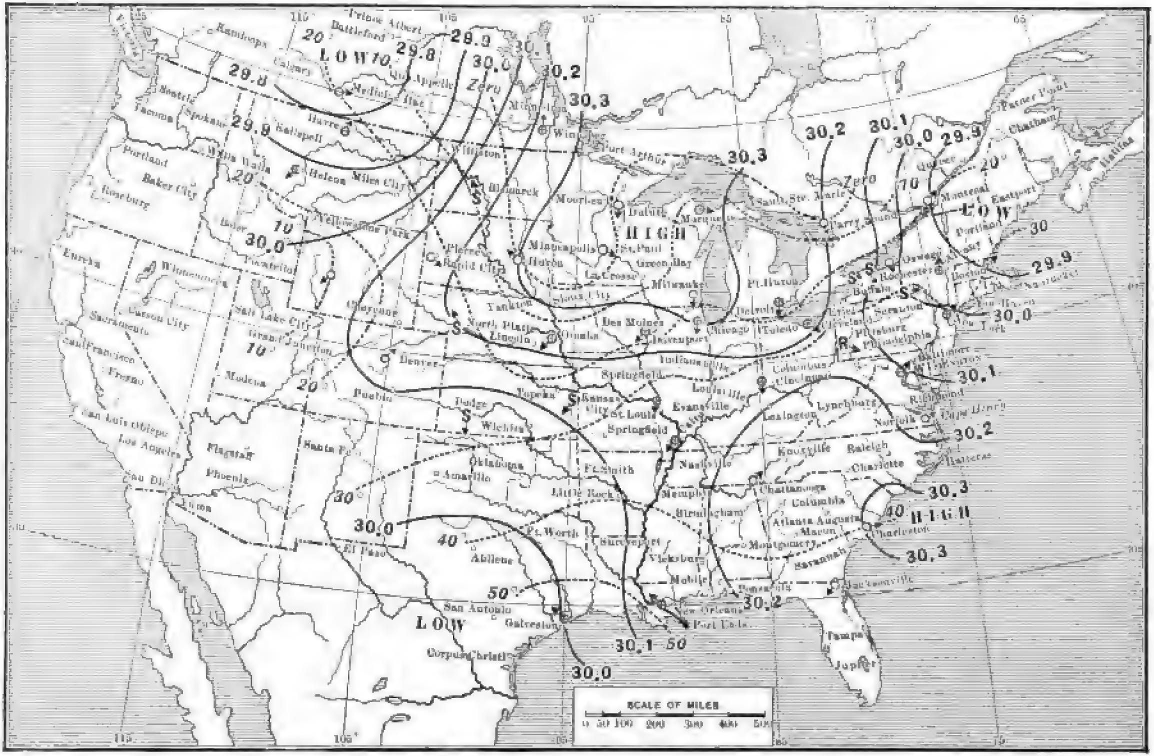


FIG. 452. — Weather conditions, January 23, 1903. The High has moved eastward. Symbols same as Fig. 448.

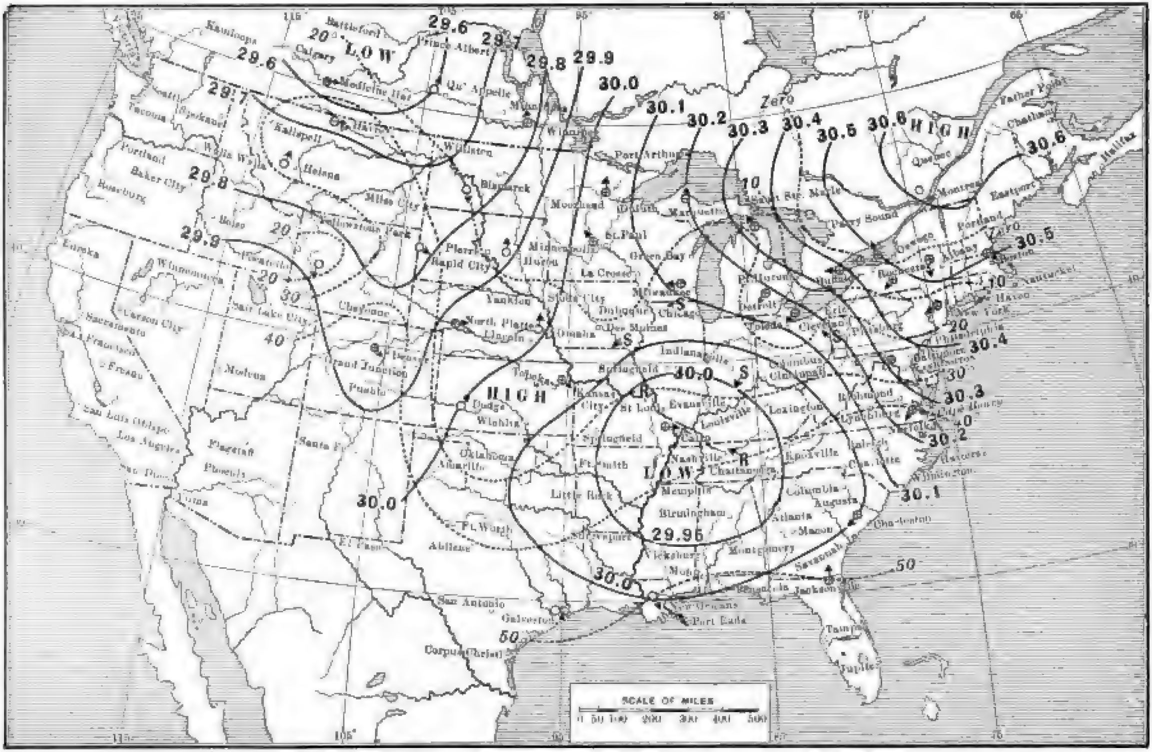


FIG. 453. — Weather conditions, January 24, 1903 (symbols same as Fig. 448). Study and compare Figs. 451, 452, and 453 to see what changes occur. Note the changes in temperature; in cloudiness; in wind direction. Compare and contrast these changes with those in Figs. 448, 449, and 450.

Few climates of the world are so variable as these of the stormy west-wind belts; and the changes in weather are very trying to the health. Consequently many diseases, such as pneumonia, grippe, and consumption, are common in these severe climates.

Summary. — *The winter weather of the west-wind belts is exceedingly variable, being cold during the passage of anticyclones, and relatively warm during the passage of cyclonic storms, whose south winds may even cause midwinter thaws.*

192. Climate of the South Temperate Zone. — Owing to the fact that there is so much water in the southern hemisphere, the changes in temperature are less extreme there than in the northern hemisphere (Fig. 435); and the winds blow with more strength and steadiness than over the irregular lands (p. 261). Otherwise the climates of the two temperate zones are much alike. Over the Southern Ocean the summer weather is damp and chilly, the winter raw and cold, though without extreme changes from warm to exceedingly cold weather. Storms are frequent and fierce, and this is why rounding Cape Horn is so dreaded by sailors.

Summary. — *Excepting for stronger, steadier winds, more uniform coolness, and less decided changes in temperature, the climate of the south temperate zone is similar to that of the north temperate.*

193. Arctic Climates. — (A) *Near the Circle.* — In summer, when the sun is above the horizon both day and night, the air, though cool and sometimes raw, is never very cold. The warmth melts the frost to a depth of two or three feet, making the soil damp and swampy. Then the grass becomes green, flowers blossom, and birds and insects appear. As in other places visited by the westerlies, storms appear in fairly regular succession, bringing rain or squalls of snow. Fogs are common on the sea and along the coast, where damp winds are chilled in passing over cold water.

In the late summer, when the sun commences to set, the days grow cooler and the nights cold. Insects disappear, birds move southward, and the land is covered with snow.

The soil freezes again, and a skim of ice appears on the ocean, growing thicker as the days become shorter. The Eskimo then gives up his kayak and takes to the sledge in search of seal, his chief food. Finally the sun is absent even at noon, and then the weather, both day and night, is bitterly cold. In winter the principal changes are those accompanying the passage of cyclonic storms. Sometimes, even in midwinter, the temperature rises so high that the Eskimo snow houses, or igloos (Fig. 525), begin to melt.

With the coming of spring the sun reappears, the snow melts, and the Eskimo abandons his igloo for a skin tent, or tupic (Fig. 524). The sea ice begins to break up and float away, and the Eskimo returns to his kayak for hunting. Then comes the summer day.

Summary.— *The Arctic summer, near the Circle, is cool, damp, and stormy. In winter, when the sun is below the horizon even at mid-day, the ground is frozen and snow-covered, the sea covered with ice, and the weather bitterly cold.*

(B) *Nearer the Pole.*—As near the pole as man has gone the climate has been found similar to that just described; but the Arctic winter night is longer and colder, the summer cooler. Even there the warmth of the summer sun is sufficient to remove the snow from much of the low ground near the coast. In upper Greenland, the northernmost land known, and far north of the highest Eskimo settlements, Peary found flowers blossoming, insects humming, and musk ox roaming about in summer.

The sea which surrounds the North Pole is everywhere covered with ice floes (p. 194), over which Abruzzi, Nansen, Peary, and others have tried to reach the pole. They must make their dash in early spring, because in summer the ice is too broken to cross on sledges, yet not open enough to allow ships to pass through. Consequently those who have tried to reach the pole have gone as far north as ships will carry them, and remained through the cold, dreary Arctic night in order to be ready for an early start. Thus far the difficulties of ice and climate have baffled the efforts of even the most hardy and venturesome explorers.

Summary. — *As far north as man has gone, the climate is similar to that nearer the Arctic Circle, though cooler in summer and colder in winter, because the sun is lower and longer below the horizon. Plants and animals live on the northmost known land. In summer the sea ice breaks up so that travel over it by sledge is impossible.*

Topical Outline, Questions, and Suggestions.

Topical Outline. — 181. **Difference between Weather and Climate.** — Weather; climate; illustration of difference; kinds of climate.

182. **Zones of Heat.** — (A) *The Five Zones:* reason for division; the zones; boundaries. (B) *Influence of Altitude:* effect of highlands; isotherms; isothermal charts; Pacific slope. (C) *Influence of Water:* contrast ocean and land; illustrations; temperature ranges. (D) *Influence of Winds:* contrast western Europe and eastern United States; eastern and western United States. (E) *Influence of Ocean Currents:* effect on winds; transference to land; contrast western Europe and eastern America. (F) *Influence of Topography:* local influences; mountain barriers; western United States; Mediterranean.

183. **Belt of Calms.** — Warmth; rain; weather on the ocean; on the land; forests; mankind.

184. **Rainy Trade-wind Belts.** — Effect of warming air; evaporation of sea water; east-facing coasts; instances; forests; Hawaiian Islands.

185. **Desert Trade-wind Belts.** — Explanation; rainfall; desert belts; horse-latitude arid climate; desert life; weather conditions.

186. **Savanna Belts.** — Location; cause of peculiar climate; effect on vegetation; instances of savannas; animals; man.

187. **The Indian Climate.** — Hot, windy season; hot, calm season; the rains; short, hot period; winter monsoon; effect of these changes on vegetation; heavy rains at base of Himalayas.

188. **Variation (in Temperate Zones) from North to South.** — (A) *Temperature:* near polar circles; near tropics; vegetation. (B) *Rainfall:* in the north; in the south; steppes. (C) *Effect of Mountains:* Contrast southern Europe and United States; effect on people.

189. **Variation (in Temperate Zones) from West to East.** — (A) *West Coasts:* climate of west coasts; contrast British Isles and eastern United States; rainfall of western United States; Chile. (B) *Effect of North-south Mountains:* western Europe; interior of Europe; western United States; country east of mountains. (C) *Interior of Continents:* rainfall; droughts; the cool north; great temperature range; continental climate; instances; explanation. (D) *East Coasts:* effect of storms on rainfall; in causing variable climate; changes from day to day.

190. **Variable Winds of the Prevailing Westerlies.** — (*a*) Sirocco: nature; cause; effects. (*b*) Blizzards or northers: location; reason for strong winds; effects. (*c*) Cold waves: nature; location; cause of cold; effects. (*d*) Foehn or chinook: location; cause of warmth; cause of dryness; effects.

191. **Weather of Eastern United States.** — (A) *Summer Weather:* (*a*) typical cycle: anticyclone; warm south winds; thunder storms; anticyclone. (*b*) Variations from cycle: droughts; general rain. (B) *Winter Weather:* regular succession of cyclones and anticyclones; precipitation; wind changes; thaws; effect of changes on health.

192. **Climate of the South Temperate Zone.** — Effect of water on temperature; on winds; summer weather; winter weather; storms.

193. **Arctic Climates.** — (A) *Near the Circle:* summer climate; plants and animals; storms; fog; change in autumn; effect on life; winter climate; effect on Eskimos; spring climate; effect on Eskimos. (B) *Nearer the Pole:* resemblance to conditions farther south; differences; life; sea ice; time of making dash toward the pole.

QUESTIONS. — 181. What is weather? Climate? Illustrate the difference. Name some different kinds of climate.

182. (A) Why may the earth be divided into zones of heat? What about the boundaries? (B) What is the influence of highlands? What is an isotherm? An isothermal chart? What is the condition on the Pacific slope? (C) What differences are there over land and water? Give illustrations. (D) Give illustrations of the influence of winds on climate. (E) How do ocean currents affect climate? Give instances. (F) What effect has topography on climate? Give instances.

183. What is the climate of the belt of calms? What is the weather on the ocean? On the land? What effect has the climate on man?

184. What effect have the trade winds on the sea? On rising coasts?

185. Why are there deserts in the trade-wind belts? Where are the great desert belts? Why are the horse latitudes arid? What are the life conditions in the desert? What are the weather conditions?

186. What is the cause of the savannas? What are the conditions there? What effect have these conditions on life?

187. Describe the Indian climate: the seasons; their cause; their effect on vegetation; the heavy rains.

188. (A) What are the conditions near the polar circle? How do the temperature and vegetation change toward the tropics? (B) How does the rainfall vary from north to south? What are steppes? Where found? What are the conditions there? (C) What is the result of the absence of lofty mountains in southern United States?

189. Why are there differences in climate from west to east?

(A) What is the climate of west-facing coasts? Why? Give illustrations. (B) Contrast central Europe with the arid West. Explain the condition in the United States. (C) What is the condition of rainfall in the interior? Why are droughts less destructive in the north? What are the temperature conditions? Why? (D) What is the cause for rainfall on east-facing coasts? How does the climate vary? Why?

190. What is the sirocco? The norther? The blizzard? What is the cause of each? Their effect? What is the cause of cold waves? Explain the foehn, or chinook wind. What are their effects?

191. (A) Describe a cycle of typical summer weather in eastern United States. What causes variations from this cycle? (B) Describe the winter weather. What causes thaws? What is the effect of the changes?

192. How does the climate of the south temperate zone differ from that of the north?

193. (A) Describe the Arctic climate in the different seasons. How do these changes influence life? (B) What is the condition of climate nearer the pole? Why is it so difficult to reach the pole?

SUGGESTIONS. — (1) Trace one or two of the isothermal lines across the charts for the United States (Figs. 433, 434) and endeavor to explain the irregularities. Do the same for one or two isotherms in the northern hemisphere of the world charts (Figs. 431, 432). Follow one or two in the southern hemisphere and account for the difference between their regularity and the irregularity of those in the northern hemisphere. (2) Make isothermal charts of the United States and the world, copying upon outline maps the isotherms in the book. (3) Study the Appendix on weather maps (Appendix H) and work out the suggestions. (4) Select and study weather maps illustrating cold waves. (5) From a series of three weather maps for successive days, describe the weather changes at a given place — say Boston or Chicago. Write down the temperature, wind direction, etc., for each of the days. (6) Make a record of local weather changes for a week. Write a short description of these changes. (7) Write a description of the climate of your home.

Reference Books. — WARD, *Hann's Handbook of Climatology*, Macmillan Co., New York, 1903, $3.00; GREELY, *American Weather*, Dodd, Mead & Co., New York, 1888, $2.50; TURNER, *Climate of New York State*, Chapter XI, *Physical Geography of New York State*, Macmillan Co., New York, 1902, $3.50; CROLL, *Climate and Time*, Appleton & Co., New York, 1890, $2.50. (See also references at end of Chapter XII.)

CHAPTER XV.

PHYSIOGRAPHY OF UNITED STATES.

THE United States illustrates in many ways the effect of physiographic conditions on the industries and development of the various sections. In previous chapters reference has frequently been made to these influences. These references, with others added, are summarized in this chapter.

194. New England. — New England is a region of very ancient mountains of hard rock, including crystalline gneisses, schists, and granites. These strata are complexly folded, and worn by denudation to the condition of hills and low mountains (Fig. 460). It is held by many that this region was worn down to a peneplain (Fig. 171), with here and there a peak, or group of peaks, rising above the general level. Such peaks have been called *monadnocks*, after Mt. Monadnock, N.H. (Fig. 455), which rises well above the fairly uniform sky line of the surrounding hilltops.

After the mountains were reduced to a low hilly condition, there was an uplift of the land, which permitted the streams to sink their valleys into the ancient mountains. This occurred so long ago that, even in the resistant rocks, the valleys have been broadened to the condition of early maturity. The Connecticut valley, in weaker sandstones and shales, has been broadened to a wide lowland (Fig. 86), with here and there hills of more resistant trap rock, like Mts. Tom (Fig. 229) and Holyoke, rising above the valley floor.

There is little mineral wealth in New England, with the exception of abundant building stone, including granite,

slate, and marble, which finds a market in many parts of the country. There is almost no coal or iron, and little metal.

Over all this region the ice sheet spread, rounding the hills and deepening some of the valleys. The residual soil was swept away, and in places, especially on steep slopes, the rock was left bare ; but usually it was covered by a glacial soil. This soil varies greatly from sterile to fertile, from thin to thick, and from clayey to bowldery (Figs. 284, 285). Over a large part of New England the glacial soil is too thin, or too sandy, or too rocky, for cultivation.

Because of the hilly nature of the land, the many steep slopes, and the poor soil, New England is not a good farming country. In fact, the forest has been allowed to remain on large areas (Fig. 189) ; and, for this reason, the more mountainous northern and western parts are among the important forest regions of the country. Under such conditions the farms are necessarily small (Fig. 457), and the area suited to farming is not nearly large enough to supply the needs of the busy manufacturing towns and cities. The great food staples, such as wheat, are brought from the West, while New England farms are devoted mainly to the production of vegetables, dairy, and similar products for neighboring towns.

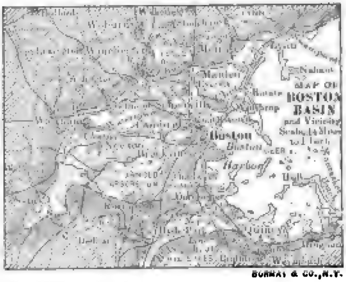
The glacial deposits have formed many lakes and turned aside many streams, which now tumble in rapids and falls over ledges which they have discovered. Hundreds of cities and towns use this water power for manufacturing, which stands at the foundation of New England's prosperity. The lakes aid in regulating the water supply.

During the glacial period the land sank and the sea entered the valleys, forming a very irregular coast line (Figs. 388, 389), with many bays and good harbors. This irregular coast line is favorable to fishing, one of the most important industries of New England ; and it early encouraged ship building, for which the forests supplied the lumber. The beautiful

scenery of this irregular coast, and the cool climate, attract many people in summer.

The many harbors have encouraged navigation. This navigation aids manufacturing by furnishing a means of bringing raw materials and of removing manufactured articles to places where they are used. Though irregular, the coast is low enough to permit the easy construction of railways; and the broad, mature valleys of the interior are also easily traversed by them. Consequently, railway lines radiate from the leading ports to cities both inland and along the coast. In this respect New England differs greatly from mountainous Norway, where communication between points along the irregular coast must be by boat.

Many of the busy manufacturing cities of New England (Fig. 456), such as Providence, Fall River, New Bedford, New Haven, Bridgeport, and Portland, are on the sea. Others, like Worcester, Lowell, Lawrence, Hartford, and Springfield, are in the interior, generally near water power. By far the largest city is Boston, on the sea. Its growth depends upon a number of favorable circumstances. It is in a central position, on that part of the coast which extends farthest into the interior of New England, and it has an excellent harbor. Communication along the coast is possible by rail and boat; the interior is easily accessible by rail; and all parts of the world are open to its commerce. All eastern Massachusetts is tributary to this port, which lies in the center of a semicircle of manufacturing towns (Fig. 454), one of the busiest manufacturing regions of the world.



BORMAY & CO., N.Y.

FIG. 454. — To show the location of Boston with the ring of surrounding towns and cities.

FIG. 455. — Mt. Monadnock, rising above the general level of the upland of southern New Hampshire.

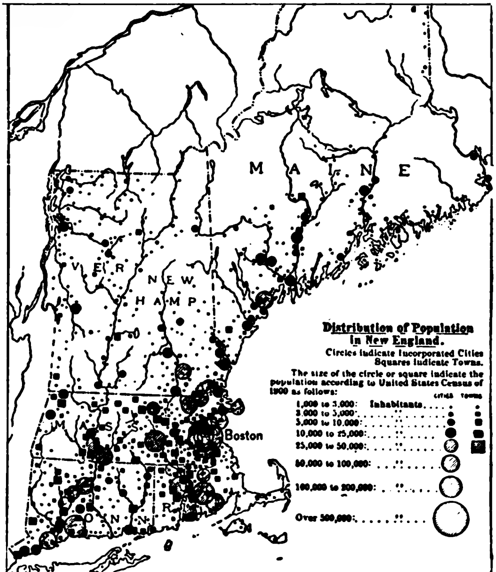


FIG. 456. — Distribution of towns and cities in New England.

Fig. 457. — St. Johnsbury, Vt. A typical view in hilly New England, showing the irregular topography and the large percentage of wooded surface.

In its physical geography, New England resembles parts of Great Britain and Scandinavia. In each case the coast is irregular, the land hilly, and much of the soil poor. Scandinavia, like the more hilly part of New England, has a large proportion of its area uncleared of forest. It is more mountainous than most of New England, and has little manufacturing; but its irregular coast has encouraged the development of fishing and shipping. Great Britain pays far more attention to manufacturing than to agriculture, and, like New England, depends upon other sections for a large part of its supply of food and raw materials.

Summary. — *New England is a region of worn-down, ancient mountains, with hilltops rising to a fairly even sky line, but with peaks and groups of peaks rising above this level, especially in the west and north. Many of these are still forest-covered. The valleys are fairly broad, even in the hard rock, favoring the construction of roads and railways. The ice sheet has left a glacial soil, which, together with the hilly condition, makes this a poor farming region. There is little mineral wealth, excepting building stone. In spite of the general absence of raw products, the water power, due to glacial interference with streams, has encouraged the development of manufacturing; and this has been further aided by the irregular coast, caused by sinking of the land. This irregular coast is favorable to fishing and to navigation. Of the many manufacturing cities Boston is most favorably situated and is, therefore, the largest.*

195. New York. — The physiography of the Empire State is more varied than that of New England. New York may be divided into four quite different regions: (1) the Adirondacks, resembling the more mountainous parts of New England; (2) the low, hilly region of southeastern New York, which resembles southwestern New England; (3) the high, hilly plateau, including the Catskills and southern and western New York; and (4) the plains which border Lakes Erie and Ontario. The ice sheet covered the entire state, excepting the extreme southwestern corner (Fig. 270). Therefore, in various parts of the state, there are moraines (Figs. 273, 274), wash plains (Fig. 275), drumlins (Fig.

287), and other glacial deposits, and gorges, water falls (Figs. 61, 67, 71, 75), rapids, and lakes.

The basis for the great growth of New York is agriculture, in which it ranks high among the states of the Union. In mineral wealth the state is not especially rich, though building stone, clay, and salt are found in excess of local needs. There is also some iron, oil, and gas, but no coal. However, the oil, gas, and coal of Pennsylvania are readily accessible; and the iron of the Lake Superior region is easily brought by water to Buffalo. Consequently, busy manufacturing cities have developed wherever facilities for transportation favored. Water power, due to glacial action, has also aided in the growth of many towns and cities.

The Adirondacks, like the higher parts of New England, are rugged, mountainous, rocky, and forest-covered (Fig. 188). Water power is used in a series of towns around their base, partly in manufacturing the products of the forest, as in making paper from wood pulp. There are some mineral resources, including iron; but distance from lines of water transportation renders the stores of building stone, and most other mineral products, of little present use. As in New England, these beautiful mountains (Fig. 299) are much resorted to by sportsmen and summer visitors.

The uplands of the Catskills, and the hilly plateau of the south and west (Figs. 145, 465), have a thin and often stony soil. This plateau is, therefore, sparsely settled, and there are large areas that are still forest-covered. The valleys, being more level, and having thicker and better soil, are dotted with farms and country villages. The abundance of creameries, for the manufacture of butter and cheese, shows that much of this region is better adapted to pasturage than to grain and other crops.

The hills are so difficult to cross, and so sparsely settled, that railways are found mainly in the larger valleys; and it is often a long, roundabout railway journey from one valley to the next. The towns and cities, such as Binghamton and Elmira, are in the larger valleys, usually at points where railways from tributary valleys enter, making these places railway junctions.

The level plains along the shores of the Great Lakes have a deep soil, deposited by the glacier and in the glacial lakes (p. 149). These lake-shore plains are among the best farming lands of the East, and the influence of the lake water gives them a climate especially suited to fruit culture (p. 166). From near Buffalo to Rome, the Erie Canal (Fig. 458) crosses these plains. Its route is now followed by railways; and the excellent facilities for transportation have encouraged the growth of numerous towns and cities, including Rochester, — at the falls of the Genesee, — Syracuse, Utica, Troy, and Albany.

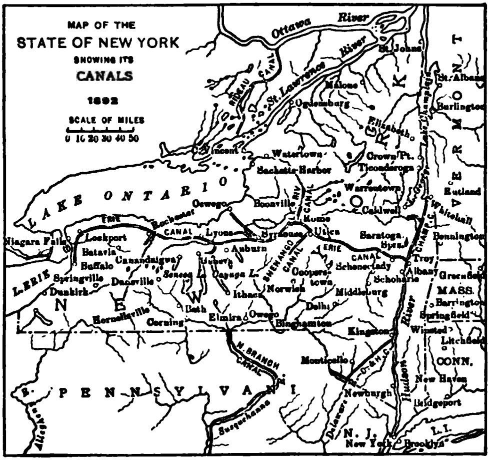


FIG. 458. — Erie Canal route.

Numerous broad, mature valleys lead back into the plateau, and in some of them are large lakes, such as Cayuga (Fig. 298) and Seneca, which have been caused by ice erosion and dams of glacial drift. These valleys and lakes afford opportunities for communication by water, road, and railway with the heart of the plateau country. In early days the Erie Canal was the only great artery connecting this interior with the sea; but railways are now added to the canal to accommodate the steady stream of trade, between the West, the interior of the state, and the sea.

The movement of goods along this route, which has aided in the growth of many towns and cities, has especially favored the cities at the two ends — New York, on the sea,

and Buffalo, on Lake Erie. The unloading of goods at Buffalo and New York, for further shipment, accounts in part for their growth. They are, moreover, supplied with abundant raw material for manufacture and have, therefore, become great centers of manufacturing and of commerce.

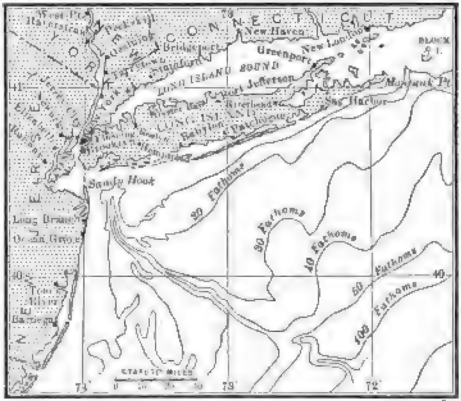


FIG. 459.— New York City and surroundings, showing the submerged channel, which extends offshore from the Hudson to the edge of the continental shelf. Before the land was lowered the Hudson occupied this channel.

By reason of its very favorable physiographic situation New York has become the largest city of the country, and one of the largest and busiest in the world. Sinking of the land (Fig. 459) has caused a fine harbor with extensive water frontage. This sinking has admitted the sea into the Hudson (Fig. 462) and into several small tributaries, even flooding low divides, thus forming islands which add greatly to the water front. As a result, an inclosed waterway has been formed behind Long Island, opening connection with New England, and another along the Hudson (Fig. 351) into the interior. The latter route, extended to the Great Lakes by canals and railways, has concentrated upon New York the shipping of a large part of the interior of northern United States. Thus the growth of New York City has kept pace with the growth of the interior.

The peculiar conditions surrounding this rapidly growing city have made the problem of living there difficult to solve. The harbor is in two states, but the main city is on a long, narrow island. There is no space for the population to easily spread outward

FIG. 460. — Relief map of southern New England. (Model by E. E. Howell, Washington, D.C.)

FIG. 461. — Relief map of United States, showing principal physiographic provinces.

in various directions from the harbor, as in many cities; instead, development had to extend up the narrow island and across the channels of the harbor. This has greatly crowded Manhattan Island, and has forced many New York business men to live at a distance, large numbers going across North River to New Jersey or across East River to Long Island. Therefore a number of cities have grown up around the splendid harbor, such as Hoboken and Jersey City, in New Jersey, and Brooklyn, now a part of New York City, on Long Island. The problem of transporting these people is more serious than in any other city; and surface, elevated, and underground lines, added to bridges, ferry boats, and railway trains, are not yet sufficient. As the city grows the problems of transportation increase.

Fig. 462. — Ideal restoration of the neighborhood of New York, if the land were reëlevated to its former level.

Summary. — *The Adirondacks resemble mountainous New England in physiography and industries; and the low, hilly region of southeastern New York resembles southwestern New England. The plateau section is hilly, sparsely settled on the uplands, but with better soil, and more inhabitants, in the broad valleys. The lake-shore plains are excellent farming land, and the Erie Canal and the railways which cross these plains have caused the growth of many towns and cities, and made much manufacturing possible. The two cities at the ends of this route, Buffalo and New York, have become of especial importance, New York having the most favorable physiographic situation of any city in the country, and hence becoming its metropolis.*

196. The Coastal Plains. — From New Jersey to Mexico there is a narrow belt of low, level land, so recently raised

above the sea that its streams are young and large tracts are undrained (Figs. 78, 79, 119–121). This coastal plains region is broadest in Florida, and extends up the Mississippi valley, which at its lower end is a filled bay. As it is south of the glacial belt, rapids and falls are practically absent from the streams; but there are lakes in the irregularities of the raised sea bottom, especially in Florida.

Much of the surface is too sandy for farming and is covered with pine forests (p. 73). Other tracts are too damp, some in the South being the seat of rice culture, which requires wet ground. Where the soil is dry and fertile enough, the coastal plains are the seat of important agriculture.

There is little mineral wealth in this belt. Sand and clay are abundant, and in some cases are shipped away; and at Charleston and in Florida there are important beds of phosphate, which is sent far and wide for use as land fertilizer.

The coast is low and often swampy, especially near the rivers, into whose mouths the sea has been allowed to enter, by a slight sinking of the land (Figs. 121, 124, 387). There are some good harbors and some large navigable bays, especially in the north, where the sinking has been greatest. But the moving sands, and the sand bars which skirt the coast (p. 214), make many of the harbors of little use. The larger bays, especially Delaware and Chesapeake bays, admit boats far into the land; and because of their gentle slope, and the absence of falls and rapids, many of the rivers are navigable to small boats. Anywhere on the level surface, roads and railways may be built; but the sparseness of settlement, and the general absence of manufacturing, make few railways necessary.

The cities are located either on the Fall Line (Fig. 125), along the inner margin of the coastal plain, or else at the head or mouth of the bays. Galveston is on a sand bar at the mouth of a bay; New Orleans is on the navigable Mississippi at the point where it comes nearest to a shallow bay, navigable in early times by small boats; Mobile, Savannah, and Charleston are on small bays; Norfolk is at the mouth of the large Chesapeake Bay.

Summary. — *The level coastal plains extend from New Jersey to Mexico. They are often so swampy, or have such sandy soil, as to be unfit for agriculture. There is little mineral wealth. The low, sandy coast has many navigable bays, due to sinking of the land; but sand bars interfere with the entrance to many by ships. The chief cities are on the Fall Line or on the coast, either at the head or mouth of a bay.*

197. The Piedmont Belt. — The low, hilly country, from New York to Alabama, between the coastal plains and the Appalachians, is known as the Piedmont belt (Figs. 461, 464, 465). It is an uplifted peneplain, with hilltops rising to a nearly uniform level, and here and there a monadnock standing above the general surface. An uplift has given the streams power to sink their valleys into the peneplain. That this was once a high, rugged, mountain region is proved by the fact that the rocks are intensely folded.

Excepting in New Jersey the Piedmont region is south of the glacial belt, and, therefore, the residual soil has not been removed from its undulating surface. This soil is usually deep and fertile, and, since the climate is favorable and the surface fairly level, this is a splendid agricultural region. It is one of the greatest cotton and tobacco belts, and, in addition, produces fruits and farm crops of various kinds.

The Piedmont belt is dotted with towns and cities, and crossed by many railway lines. The Fall Line cities (Fig. 125) are along its eastern margin, the two largest being Philadelphia and Baltimore, also near the head of navigation on large bays. Washington is similarly situated. Philadelphia and Baltimore, like Boston and New York, have become great seaports because of good harbors and connection with a productive interior. Being shipping points for the exports and imports of the interior, these cities have naturally become great manufacturing centers. Manufacturing has been further encouraged by the readiness with which coal and iron are obtained.

The largest city away from the Fall Line is Atlanta, which, like many other towns and cities of the South, has become of importance as a center for the manufacture of cotton, lumber, and other local products. Atlanta owes its development largely to the fact that it lies at the point of intersection of a number of railway lines, including those that pass around the southern end of the Appalachians.

Summary. — *The Piedmont belt is an uplifted peneplain, with a fertile residual soil and a favorable climate. It is, therefore, an excellent agricultural region, producing especially tobacco and cotton. It is dotted with towns and cities, the largest being on the Fall Line. Among these cities are Philadelphia, Baltimore, and Washington, also at the head of large bays.*

198. The Appalachian Belt. — This belt, extending from New York to Alabama, parallel to the Piedmont, may be divided into two parts, — the eastern, or Appalachian proper, and the western, or Appalachian (Alleghany) plateau (Figs. 461, 464, 465). The eastern section is a true mountain region of folded rock, while the western portion is true plateau with horizontal strata. Both are so rugged that much of their area is unsuited to settlement and, therefore, still forest-covered (Figs. 85, 146). The ruggedness is due to so recent an uplift that the streams have cut deep valleys.

Fig. 463. — The Potomac Water Gap.

For a long time these rugged, forest-covered belts served as a barrier to westward migration; and even now, along all but a few lines, they are passed with difficulty. The ridges

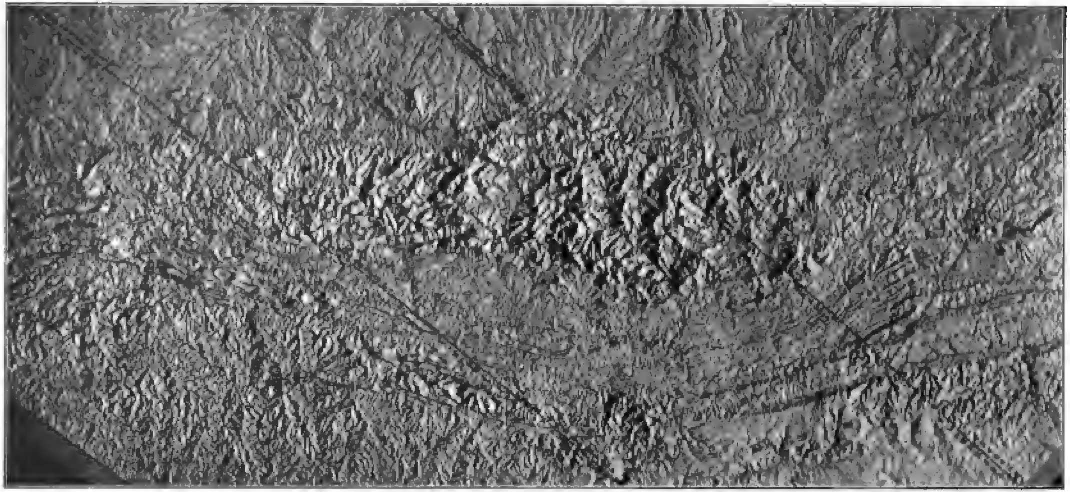


FIG. 464. — Relief map of the Appalachian region, where Tennessee and the Carolinas come together (north in upper right-hand corner). The Piedmont belt occupies the lower portion. Above that is the high, rugged Appalachian region of western North Carolina. Nearer the top are a series of long, low Appalachian ridges and broad valleys, — a mature mountain region. In the upper part is the plateau of Tennessee, Kentucky, and West Virginia, deeply dissected in West Virginia, on the right-hand side. It is proposed to make a great forest reserve of part of this area. (Model by E. E. Howell, Washington, D.C.)

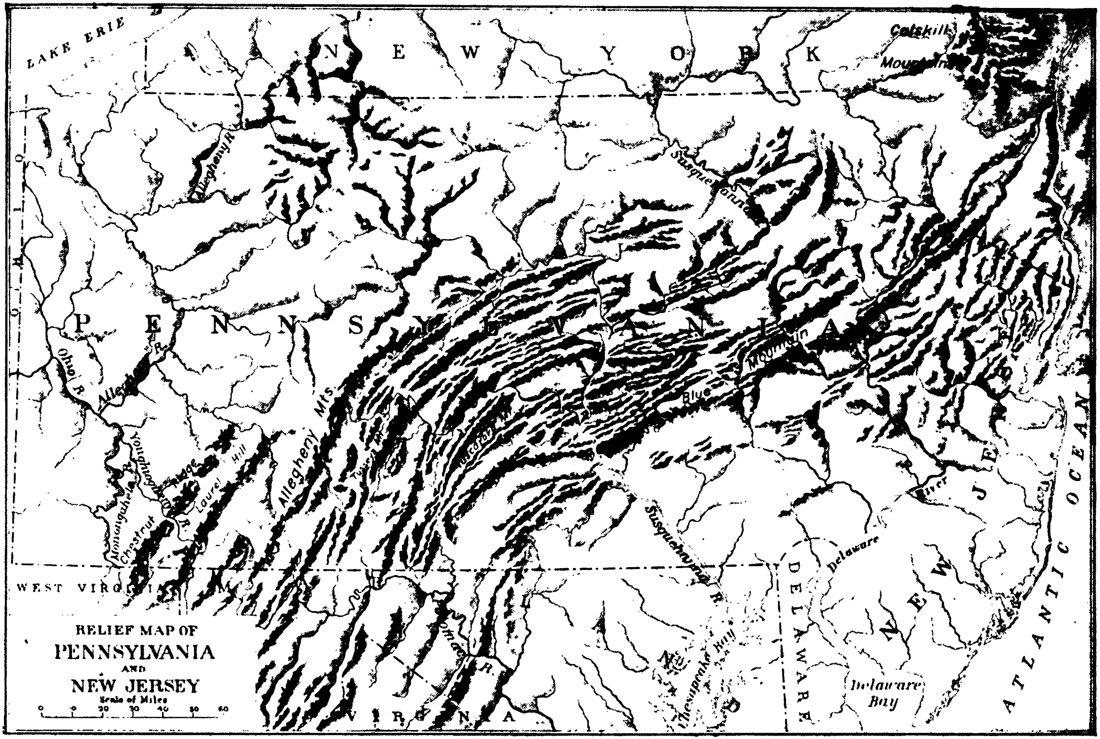


FIG. 465. — Relief map of New Jersey and Pennsylvania. Coastal plain in the extreme east; next the level Piedmont belt; then the long mountain ridges of the Appalachians, with broad valleys between; and, still farther north and west, the rugged plateau, reaching into Ohio and New York.

are crossed by water gaps (Figs. 172, 192, 193, 463, 467), which the trails of the Indians and trappers, the wagon roads of the early settlers, and the railways and canals of present-day commerce all have followed. The principal lines of passage are along the Cumberland, Potomac, Susquehanna, Delaware, and Mohawk gaps.

This belt includes some of the most sparsely settled regions of eastern United States (p. 84), and is an important timber reserve. It would be still less populous if it were not for two important facts. In the first place, where the rock is soft the valleys have been so broadened as to invite an agricultural population (Fig. 466). This is best illustrated by the broad, fertile limestone valleys of New Jersey, Pennsylvania, the Shenandoah valley of Virginia, and the Tennessee valley. In the second place, the rocks contain stores of valuable mineral (p. 108), the most important being coal, iron, oil, and gas. The coal and iron have been exposed in many of the deep valleys.

These conditions have led to the development, not only of mining industries, but of important manufactures. Of the many busy centers of mining and manufacturing the greatest is at Pittsburg and Allegheny, where the Monongahela and Allegheny unite to form the Ohio. This point has water connection with a wide area; and the meeting of railways where the valleys come together has added facilities for extensive railway transportation. Therefore iron and other raw products for manufacture are easily obtained, and the manufactures are readily distributed. This favorable situation was caused by the effect of the ice sheet (p. 155).

Scranton and Wilkes Barre, farther east in the anthracite coal fields, have also developed into important mining and manufacturing cities. Indeed, all Pennsylvania has had its growth stimulated by its great mineral resources, and especially its coal.

Throughout the Appalachian belt similar mineral wealth is causing development. In no place is this better illustrated than at

Birmingham, Ala., where, within a radius of a few miles, are found abundant stores of coal, iron, and limestone, the three materials necessary for iron smelting. Under such favorable conditions a large manufacturing city has rapidly grown.

Summary. — *The Appalachian belt, extending from New York to Alabama, consists of* (1) *true mountains, and* (2) *a plateau portion. Both are for the most part rugged, sparsely settled, and, over large areas, forested, forming a barrier which was first and most easily crossed along the water gaps. Some of the broad valleys are good farm land, and there is much mineral wealth, especially coal. This has given rise to a number of important mining and manufacturing centers, of which the Pittsburg-Allegheny region is most important.*

199. The Central Plains. — The region that slopes toward the Mississippi river, from the Rocky Mountains on one side and the Alleghany plateau on the other, is for the most part an expanse of level plains (p. 76). This levelness is due to two facts : (1) the rock strata are nearly horizontal ; (2) the valleys are mature. In a few places the strata have been disturbed by mountain folding, as in the Black Hills and the low mountains of central Texas, Indian Territory, Arkansas, and southern Missouri (Fig. 461). Around Lake Superior is another low mountain area, a southward extension of the ancient mountain land of central Canada.

In such a level country, railways may be built almost anywhere, though they naturally follow the valleys. These are so broad and open that they are well settled, quite unlike the steep-sided valleys of the Alleghany plateau. The large rivers have so nearly approached grade that they are navigable for long distances. The Mississippi, for example, is navigable for 1000 miles from the sea, as far as St. Paul.

The ice sheet covered the northern part of these plains (Fig. 270), filling the valleys with drift and thus making the surface more level (Fig. 294). These glacial deposits have turned many streams out of their valleys, causing falls and rapids, as in the

Fig. 466. — **A broad valley in the Appalachian Mountains of Pennsylvania. Where this stream crosses the hard rock of the mountain ridges its valley contracts to narrow water gaps.**

FIG. 467.—The Delaware Water Gap, a narrow valley where the Delaware River cuts across a ridge of hard conglomerate in the Appalachians.

case of the Falls of St. Anthony at Minneapolis. Many ponds and lakes were also formed, as in the low, hilly country of Minnesota, in which there are said to be 10,000.

One of the most important effects of the glacier was to make the Great Lakes water route (p. 156) which, supplemented by canals, offers facilities for interior water transportation that are not equaled on any other continent. Continuous water transportation is possible from the sea to Duluth, a distance, via Montreal, of over 2000 miles.

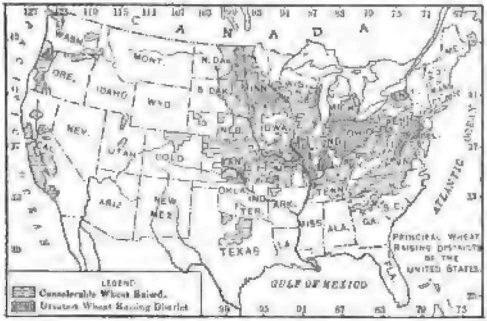


FIG. 468.—Notice to what extent the wheat of the country is raised in this section. Much the same is true of other grains.

The generally level surface, the fertile soil, and the climate have combined to make these plains one of the greatest of agricultural regions (Fig. 468). The further fact that large sections of prairie were treeless helped in the rapid development of the region. The agricultural products vary with the climate from hardy grains in the North to tobacco and cotton in the South. In the hilly lands and along the rivers, especially in Michigan, Wisconsin, and Minnesota, there is forest, from which much valuable timber is obtained.

The western part of this plains region (west of the 100th meridian) has an arid climate (Figs. 127, 129), unfitting it for agriculture without irrigation (p. 287). This part of the Great Plains is the seat of an important grazing industry (Fig. 128).

There are great stores of mineral wealth, including building stone, clay, salt, lead, zinc, oil, gas, and coal; and the copper and iron of the Lake Superior region contribute to the natural resources. The almost unlimited supplies of coal, widely distributed, make manufacturing possible throughout almost the entire area. The farms, mines, and forests supply the raw materials, and the excellent facilities for transportation permit the distribution of raw and manufactured products.

Fig. 469. — Sketch map to show the variety of materials available for shipment by the Great Lakes.

It is natural that there should be busy manufacturing cities along the large, navigable rivers. The greatest of these river cities are St. Louis, on the Mississippi, near the mouth of the Missouri, and Cincinnati and Louisville, on the Ohio. That the situation of St. Louis, near the junction of two great rivers, is favorable, is shown by its marvelous growth, making it the fourth largest city in the United States. Its position makes it a manufacturing and distributing point for products from north, south, east, and west.

Another great industrial community is found at the head of navigation on the Mississippi — the twin cities of St. Paul and Minneapolis. The latter has the further advantage of a fall in the Mississippi, supplying water power. New Orleans, near the mouth of the Mississippi (p. 306), and Pittsburg, at the head of the Ohio (p. 309), are closely related in prosperity to the fertile interior plains, for they are in close communication with them by water and rail.

Along the lake route many important cities have developed: in Canada, Montreal and Toronto; in United States, Buffalo, Cleveland, Toledo, Detroit, Chicago, Milwaukee, and the two neighboring cities of Duluth and Superior, besides many smaller places. Each of these cities profits by the commerce that the water route opens to it; and each is able to receive the raw products of the entire lake region (Fig. 469). Iron, one of the most important of these products, must be brought to the coal fields for smelting, and all lake ports near the coal fields share in the benefit. With the recent wonderful development of the iron region there has been a corresponding growth of the lake ports.

Each of these cities has some special reason for its growth at that particular point. Duluth-Superior and Buffalo are at the two American ends of the lake route. Toronto is on a good harbor on the Canadian side of Lake Ontario, opposite the Welland Canal. Montreal is at the head of navigation for large ocean boats, and at the foot of a rapid in the St. Lawrence, around which a canal has been built. Cleveland and Toledo are on good harbors on Lake Erie, and near extensive coal fields. Detroit is on a narrow strait, through which lake traffic must pass, and at a point where railways cross from United States to Canada. It is, moreover, practically at one end of Lake Erie. Milwaukee is on a good lake harbor backed by a fertile country.

Of all the cities in this section, Chicago has the best natural site and has, consequently, grown the fastest. It is no accident that it has become the second largest city of the country; nor is there any reason to expect that its growth will not continue. The small harbor, around which Chicago started, was scoured out by the overflow stream of the glacial lakes that existed while the ice sheet was melting away (Fig. 280). The city soon outgrew its small natural harbor, but continued to prosper because of its favorable situation.

Like Buffalo, Toledo, Detroit, and Duluth, it occupies a

position near the end of a great lake. With other lake ports it shares all the advantages of lake shipping; and, like several of them, it is near coal fields, and in the midst of a fertile agricultural region which supplies raw products and a market for manufactured goods. More than this, it is a natural railway center; for at this point roads from the West and Northwest, swinging around the southern end of Lake Michigan, join railways from the South and East. For these reasons Chicago has become a great manufacturing and commercial center, being a distributing point for a wide area of country. It is a center of distribution for some products, such as meat products, for cities even as far away as the seacoast.

Summary. — *The Great Plains region, though mostly level, has a few low mountainous sections. The northern portion was covered by the ice sheet. The greater part of the plains region is adapted to agriculture; but some of the more hilly portions are forested. The western portion is arid, and hence devoted mainly to grazing. The Plains have great mineral resources, notably coal and iron, and consequently have become an important manufacturing section. The navigable rivers and broad valleys have encouraged the growth of a number of large river cities of which St. Louis is the greatest. The Great Lakes water route is even more important for navigation, and hence has a series of large and busy manufacturing cities. Of these Chicago is the largest. This, the second city in the country, has a fine natural situation at the end of one of the lakes, in the midst of a fertile agricultural country, and near extensive coal fields.*

200. The Far West. — This broad area is mainly a great plateau with mountain ranges rising here and there. Both the mountains (Figs. 158, 161, 165, 166, 470, 471) and plateaus (Figs. 137, 138, 141, 476–478) are so young that they are very rugged. Yet there are many broad mountain valleys and extensive areas of level plateau, so that, if the climate favored, this might become much more important as an agricultural region. Over most of this area the climate is so arid that the land is suited only to grazing; and vast

Fig. 470.— A view in the Rocky Mountains of Colorado, near the timber line, showing the steep slopes and small amount of surface available for farming.

Fig. 471.— A railway line crossing the Rocky Mountains near Georgetown, Colo.

Fig. 472. — A trail in the mountains of western United States.

numbers of cattle, sheep, horses, and goats are raised on the plains, plateaus, and mountain slopes. Parts of Nevada, southern California, and Arizona are true desert, with too little grass and water even for grazing (Fig. 150).

On the other hand, some of the high plateaus and mountain valleys have rainfall enough for agriculture, and many of the mountain slopes and higher plateaus are forested. One very large area, including the northern half of California, western Oregon, and much of Washington, has sufficient rainfall to make it a very important agricultural region.

Farming is also carried on wherever irrigation is possible; but, unfortunately, the water supply is lowest in summer. One of the great problems of the future, in which the entire country is interested, is how to store the winter rain and melting snow for use in summer. The government is now at work on this problem, and reservoirs are being built which will supply water to reclaim thousands of square miles of arid land. In this way the West may be made to support a much larger population.

The mountain rocks contain great stores of mineral, much of which have not yet been developed. No part of the world equals this section in the production of precious metals; and, in addition, much copper, lead, and zinc are obtained. Coal, oil, gas, iron, salt, building stone, and many other mineral products, though found in many places, are not yet produced in large quantities. They are among the undeveloped resources of United States.

Scattered through the Far West are many thriving towns and cities (Figs. 133, 190), some engaged in mining, some in manufacturing, and all serving as distributing centers for surrounding sections. Of these the largest are Denver, at the eastern base of the Rocky Mountains, Salt Lake City in Utah, and several cities on the Pacific slope. Denver is a railway center and an important distributing and manufacturing center for a great mineral section.

On the Pacific slope are Seattle, Tacoma, and Portland, manufacturing and shipping points for a productive agricultural country. Their harbors, like that of San Francisco (Fig. 350), have been caused by sinking of the land. The great agricultural and mineral resources of California have made San Francisco a busy manufacturing and shipping center, already ranking in size as the ninth city in the country. With the growing trade across the Pacific, this city seems destined to take a still higher rank.

The Far West is justly noted for its magnificent scenery. No part of the world rivals in grandeur the canyon of the Colorado (Figs. 1, 139, 478); in no part of the world is there the equal of the Yellowstone Park, with its hot springs (Figs. 243, 474), geysers (Figs. 244, 473), and canyons (Fig. 480); nowhere is there another Yosemite (Fig. 475). But these are only some of the best known of the points of scenic interest in the West. Symmetrical volcanic cones (Figs. 214, 215), rugged peaks and glaciers, and grand mountain valleys (Figs. 57, 66, 472) and lakes, whose surroundings are nowhere excelled in picturesqueness, are found in various parts of the West. Each year the stream of travel toward these centers of scenic attraction increases.

The dry climate, unfavorable to agriculture, is favorable to health; and, consequently, many parts of the West — Colorado, New Mexico, Arizona, and southern California, especially — are much resorted to. The city of Los Angeles owes a large part of its growth to the number of people who have gone there in search of a healthful climate. The climate of southern California is so sunny and balmy, like that of the Mediterranean, that, wherever irrigation is possible, the orange grows to perfection. It is one of the most attractive parts of the country.

Summary. — *Except in the northwestern part, and on some high plateaus and mountain slopes, the plateau and mountain area of the West has a climate too dry for agriculture without irrigation. Much of it is, therefore, essentially a grazing region. The building of reservoirs, to store the winter and spring floods for use in summer, is greatly increasing the area of agricultural land. The West is an*

FIG. 473. — Eruption of Fountain geyser in the Yellowstone Park.

FIG. 474. — The Hot Springs near the entrance to Yellowstone Park.

FIG. 475. — Granite peaks in the Yosemite valley, California.

important mineral belt, being the greatest producer of precious metals in the world. Of the cities, the largest in the eastern Rockies is Denver. On the Pacific slope are several cities, of which San Francisco is the largest, having a fine location, on a splendid harbor, the outlet of a productive country. The West is noted for its wonderful scenery, especially the Colorado Canyon, Yellowstone Park, and Yosemite valley; the arid climate also makes the Southwest a favorite health resort.

Topical Outline and Review Questions.

Topical Outline. — 194. **New England.** — (*a*) Surface features: rocks; effect of denudation; monadnocks; uplift; nature of valleys; mineral products. (*b*) Farming: glacial soil; reasons for forests; small farms; food supply. (*c*) Manufacturing: water power; lakes. (*d*) Coast line: cause for irregularity; fishing; ship building; summer resorts; navigation; effect on manufacturing; comparison with Norway. (*e*) Cities: location; Boston; reasons for growth. (*f*) Comparison: with Scandinavia; with Great Britain.

195. **New York.** — (*a*) General features: four divisions; glacial action; agriculture; mineral resources; manufacturing. (*b*) Adirondacks: forests; manufacturing; mineral; summer resorts. (*c*) Plateau region: uplands; valleys; agriculture; railways; cities. (*d*) Lake plains: cause of levelness; farming; Erie Canal route; cities; valleys leading into the plateau. (*e*) Two largest cities: influence of canal; causes of growth. (*f*) New York: cause of harbor; water communication with New England; with the interior; peculiar situation; effect on homes; on transportation.

196. **The Coastal Plains.** — Extent; surface features; agriculture; mineral wealth; coast line; interior navigation; railway transportation; location of cities; instances.

197. **The Piedmont Belt.** — Surface features; peneplain; soil; agriculture; Fall Line cities; Philadelphia and Baltimore; Atlanta.

198. **The Appalachian Belt.** — (*a*) Surface features: extent; two divisions; ruggedness; effect as barriers; river gaps. (*b*) Industries: lumber; agriculture; mineral resources. (*c*) Cities: Pittsburg and Allegheny; Scranton and Wilkes Barre; Birmingham.

199. **The Central Plains.** — (*a*) Surface features: extent; cause of levelness; mountain areas; broad valleys; navigable rivers; effect of glacier; Great Lakes water route. (*b*) Industries: agriculture; lumbering; grazing; mineral resources; manufacturing. (*c*) River cities: St. Louis; Cincinnati; Louisville; advantages of location of St. Louis; St. Paul and

Minneapolis; New Orleans; Pittsburg. (*d*) Lake cities: cities on the lakes; importance of situation on the lakes; location of Duluth-Superior; Buffalo; Toronto; Montreal; Cleveland; Toledo; Detroit; Milwaukee; Chicago,—origin of harbor, position, commerce, surrounding country, railway center, manufacturing and distributing center.

200. **The Far West.**—(*a*) Surface features: plateaus; mountain ranges. (*b*) Climate and agriculture: arid climate,—grazing, desert; humid sections,—location, forests, agriculture; irrigation; storage reservoirs. (*c*) Mineral: precious metal; other minerals. (*d*) Cities: Denver; Seattle; Tacoma; Portland; San Francisco,—its harbor, region tributary, growth of city. (*e*) Scenery: Colorado; Yellowstone; Yosemite; other attractions. (*f*) Health: favorable climate; Los Angeles.

Review Questions.—194. What are the surface features of the uplands? What is a monadnock? What is the condition of the valleys? Why? What mineral products are there? What effects had the ice sheet on the soil? Explain the condition of farming. What effect has this on food supply? What conditions have favored manufacturing? Explain the irregular coast. What important effects has this coast? Where are the cities located? What conditions have favored the growth of Boston? Compare New England with Scandinavia and Great Britain.

195. What are the four divisions of the state? What effect has the glacier had? What are the natural resources? What is the condition and what are the industries of the Adirondacks? What is the condition on the plateau upland? In the valleys? Where are the cities of the plateau section? What causes the levelness of the lake plains? What are the industries there? What effect has the Erie Canal? What is the condition of the valleys leading into the plateau? Why have cities grown at the two ends of the water route? What conditions of physiography have favored the growth of New York City? What effect has the peculiar location of the city on homes? On transportation?

196. What is the condition of the coastal plains? What about agriculture? Mineral wealth? What is the condition of the coast line? What favors internal navigation? Where are the cities?

197. Explain the surface features of the Piedmont belt. What is the condition of agriculture? What accounts for the greatness of Philadelphia and Baltimore? What accounts for the growth of Atlanta?

198. What are the two divisions? What are the surface features? How is this rugged barrier crossed? What are the resources of the belt? What conditions have favored the growth of Pittsburg and Allegheny? Scranton and Wilkes Barre? Birmingham?

199. Why are these plains level? Where are the mountainous sections? Why are the rivers favorable to navigation, and the valleys to

settlement? What effects had the ice sheet? Of what importance is the lake route? What conditions favor agriculture? Where are forests found? What is the condition in the western part? What important mineral resources are there? What conditions favor manufacturing? Locate the three largest river cities. How is the situation of St. Louis especially favorable? What advantages of location have St. Paul and Minneapolis? How are New Orleans and Pittsburg related to this region? Name and locate the leading lake cities. What general advantages do they share? What especial reason is there for the growth of each? What is the reason for the exact location of Chicago? What special advantage has it?

200. What are the surface features? What is the general condition of the climate? What is the effect of this on industry? Where are the humid sections? Why are storage reservoirs necessary? What valuable minerals are found? For what is Denver important? Seattle, Tacoma, and Portland? What causes the harbors? What has favored the growth of San Francisco? What scenic attractions are there in the West? In what way is the dry climate favorable? What effect has this had on Los Angeles?

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CHAPTER XVI.

RIVERS OF UNITED STATES.

ALMOST the entire United States is tributary to seven large river systems (Fig. 479) and a series of smaller streams, most of which flow eastward or southward into the Atlantic and Gulf. The greatest amount of drainage is into the Atlantic, including the Mississippi, which drains two fifths of the whole country; next in area is the Pacific drainage; while a small section drains into the Arctic through the Red River of the North. As has been shown in previous chapters, the river systems have been highly important factors in the development of the country. They have been a source of food; they have supplied water power; and they have served as pathways of exploration and commerce. The present chapter considers this subject more specifically.

201. The Columbia. — The Columbia rises on the western slopes of the Rocky Mountains, flows across an arid region, and enters the sea in a region of abundant rainfall. Its length is 1400 miles, and it drains over 200,000 square miles. The lower Columbia is formed by the union of two rivers, the Columbia and Snake. From the Rocky Mountains to the Cascades, both the Snake from the south and the Columbia from the north flow across a vast lava plateau (p. 125). These rivers and their tributaries have cut young canyon valleys in this plateau (Fig. 476), in some places 2000 to 3000 feet deep, out of which it is impossible to lead the water for irrigation. There are many rapids and falls, including the Shoshone Falls, so that, throughout the greater part of their course, the rivers are unnavigable.

FIG. 476. — Relief map of Washington, showing the drowned coast at Puget Sound, the Cascade Ranges, and, farther east, the broad lava plateau through which the Columbia flows. The southern boundary of the state is the Columbia, where it crosses the Cascade Ranges. (Model by S. Shedd.)

Fig. 477. — Model of the Grand Canyon of the Colorado (by E. E. Howell, Washington, D.C.).

Instead of serving as pathways, these canyon valleys are barriers to passage ; but in its lower course the Columbia is an important aid to travel, for it crosses both the Cascade and Coast Ranges, thus opening gaps across these mountains, which a railway follows. Sinking of the land has admitted the tide for over 100 miles, as far as Portland ; and navigation by river boats is possible up the river even above the junction of the Columbia and Snake (Fig. 481).

Large numbers of salmon pass up this river to lay their eggs, or spawn; and the catching and canning of these fish is an important industry along the lower course of the Columbia.

Summary. — *The union of the Columbia and Snake rivers makes a great river system. In their upper parts these rivers occupy canyons in a broad lava plateau, and these valleys are barriers to travel; but the lower river is navigable, opening a pathway across the mountains, and admitting ocean boats for* 100 *miles, as far as Portland.*

202. The Sacramento. — The extensive fertile valley of California (Fig. 114), between the Sierra Nevada and Coast Ranges, is drained by the Sacramento River where it crosses the mountains at the Golden Gate. Sinking of the land has admitted the sea, forming San Francisco Bay and connecting the valley of California with the sea (Fig. 350). The Sacramento is 400 miles long and has a drainage area of about 58,000 square miles. It is made by the union of two rivers which extend along the great valley, — the Sacramento from the humid north, the San Joaquin from the arid south. For some distance each is navigable to small boats.

These rivers are fed by short streams from the inclosing mountains, where they occupy canyons. At the base of the mountains these tributaries are building low alluvial fans, and are engaged in slowly filling the great valley (p. 68). Over the alluvial fans the streams flow in shallow valleys, from which water is easily led for purposes of irrigation. The water of the mountain streams is also used in hydraulic mining for washing gold from the river gravels.

Summary. — *The Sacramento, formed by the union of San Joaquin and Sacramento, is fed by small mountain streams whose water is useful for irrigation and for hydraulic mining. Breaking through the Coast Ranges at the Golden Gate, this river connects the great California valley with the ocean.*

203. The Colorado. — The Colorado River, like the Nile, has its source among mountains which supply it with so much water that it is able to flow completely across a vast stretch of arid and desert country. Its length is about 2000 miles, and it drains about 225,000 square miles, being formed by the union of two large streams, — the Grand and Green. For fully half its length the Colorado flows in canyons cut in a high plateau, which in places is over 8000 feet above sea level. The depth of the canyons varies from a few hundred feet to over 6000 feet in the Grand Canyon, which is over 200 miles long (p. 82). At the lower end of the Grand Canyon the country becomes open and the river crosses fully 300 miles of desert to the Gulf of California. In its lower course the river flows over a floodplain and delta.

Without exception the Colorado is the most remarkable river in the world (Figs. 1, 139, 477, 478). No canyon equals the Grand Canyon in size or magnificence. For long distances it is impossible to descend to its bottom over the precipitous sides, and the canyon forms an absolute barrier to travel. It would make an excellent boundary between countries. Only by undergoing the utmost hardships and dangers is it possible to pass through the canyon, and few explorations in America have been more daring than that of Major Powell's party, which made the first descent (Fig. 139).

On both sides rise steep, impassable precipices, often from the water's edge; and the river tumbles over a succession of rapids, in which it is almost impossible for a boat to live. Here and there short tributaries enter, with slopes so steep that the occasional heavy rains wash large bowlders down them into the main stream. These form one of the chief causes for the rapids.

A mile of successive rock strata is revealed in this enormous

gash in the crust, and at their base is a buried mountain area, once dry land, now covered by a thick series of sedimentary strata. The river is flowing with such a steep slope that it is rapidly cutting its canyon deeper, and weathering is wasting back the cliffs, which form a multitude of irregular and rugged mesas, buttes, ridges, and spurs. Where hard rocks outcrop, there are steep cliffs; where weaker layers occur, the slopes are gentler; where the cliffs have wasted back, flat terraces often extend from their base; and everywhere there is a wonderful and varied coloring of the rock walls. In places, where the cliffs have wasted back, the canyon slope consists of a series of hard rock terraces with level tops and steep fronts. This is especially true of the older, upper portion where the cliffs have wasted farther back.

Fig. 478. — A view in the Marble Canyon, one of the canyons of the Colorado.

In this arid country few large tributaries enter the river, and these bring little water, for throughout most of the area the annual rainfall is less than 10 inches. All the larger tributaries are from the southern and eastern sides, because the river flows so near the edge of the arid Great Basin that tributaries from that side must be few and small. These tributaries themselves are in canyons, and between them are broad areas of tableland with many mesas and buttes, — a typical young, arid land plateau (p. 81).

Summary. — *The Colorado, fed by rains and snows from the Rocky Mountains, flows for nearly* 2000 *miles across an arid and,*

in places, a desert country, for a large part of the distance in deep canyons sunk in the plateau. The Grand Canyon has a depth of 6000 feet. Its steep sides are often impassable, and they are carved and sculptured into a great variety of forms. There are few large tributaries, and these bring little water.

204. The Great Basin. — The Great Basin, a region of interior drainage with an area of over 200,000 square miles, lies between the Rocky and Sierra Nevada mountains. It is bounded on the north by the Columbia plateau, and on the south by the Colorado plateau. A number of disconnected parts unite to form this general basin, one of them, Death Valley, being below sea level. The surface of the Great Basin is crossed by a number of short mountain ranges, known as the Basin Ranges.

The entire region is arid, and in places a true desert (Fig. 150). The short, mountain streams quickly disappear, either by evaporation or by percolation into the loose gravels of their alluvial fans. Some of the streams terminate in salt lakes, such as Great Salt Lake; others in alkali flats or playa lakes (p. 169).

There is too little water for extensive irrigation, and, consequently, most of the Great Basin is sparsely settled. The most densely settled part is the fertile, irrigated region of which Salt Lake City (Fig. 133) is the center. If the rainfall were greater, water would gather in the basins, forming several hundred lakes. During the glacial period, when the climate of the Great Basin was moist, large fresh-water lakes filled some of these basins (p. 164).

Summary. — *The Great Basin is an arid region of interior drainage, consisting of a number of smaller basins. It is in places true desert, and, for the most part, sparsely settled.*

205. The Rio Grande. — This river resembles the Colorado in some respects. It is almost as long (1800 miles), and has a greater drainage area (240,000 square miles). Like the Colorado, the Rio Grande receives so large and permanent a water supply from its mountain sources that it is able to flow across an arid country to the sea. Like the Colorado, too, it has cut deep canyons in the plateau; but they are neither so deep, so long, nor so continuous as the canyons of the Colorado. In a number of sections the

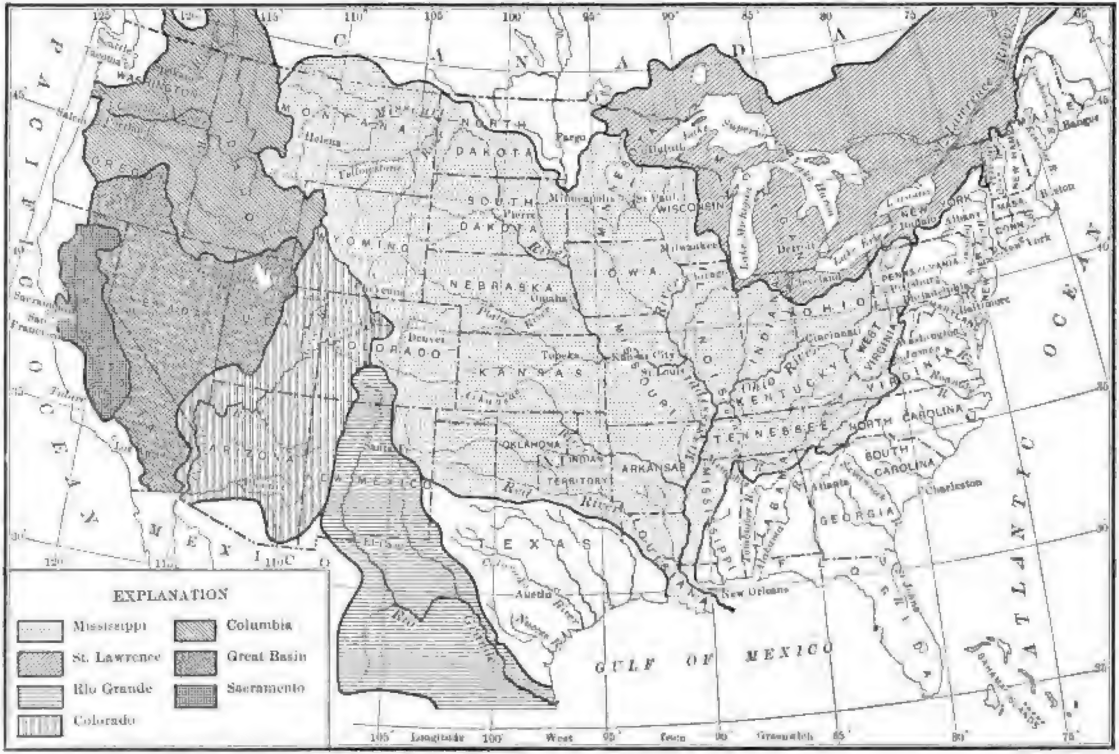

Fig. 479. — Main drainage basins of the United States.

FIG. 480. — Yellowstone Falls and Canyon, cut in lava.

valley broadens, and is bordered by floodplains and low, terraced land, over which the river water is easily led for irrigation. Therefore, from Colorado to Mexico, there are many irrigated sections and numerous thriving towns and cities. The only large tributary is the Rio Pecos, which resembles the main river.

Owing to the openness of parts of its valley, and the sandy nature of its bed, the Rio Grande loses much of its volume in crossing the arid country and is sometimes dry in summer. But in winter and spring it is a large river, rising especially high during the melting of the mountain snows. It is always heavily charged with sediment, and in places is aggrading its valley. At its mouth a delta is being built, causing a slight bulge in the coast line (Fig. 371). In its lower portion the Rio Grande is navigable to small boats; but at present this is of little use, since that region is arid and sparsely settled.

Summary. — *The Rio Grande, supplied with water from the Rocky Mountains, flows across an arid region to the sea, receiving only one large tributary, the Pecos. Its course is marked by alternate canyons and open valleys, which are irrigated and well settled.*

206. The Mississippi System. — This enormous river system, the longest and one of the largest in the world, has a length, along the Missouri, of 4300 miles and a drainage area of 1,250,000 square miles. It receives a large number of tributaries, some very long, including the Red (1200 miles long), Arkansas (2170 miles), Missouri (3000 miles), and Ohio (975 miles). Each of these tributaries has large feeders, some of them great rivers; for example, the Platte (900 miles) and the Yellowstone (1100 miles) are tributaries of the Missouri. There are over 10,000 miles of navigable water in the Mississippi system (Fig. 481).

The Mississippi valley is a broad depression, a lowland left by the greater uplift of the land on either side. Most of the streams follow consequent courses down the slopes of these uplifted sides. This depression has existed for many ages, at first

as an interior sea, into which sediment was brought by streams from the neighboring highlands; later it was transformed by uplift to dry land plains.

As a whole, the Mississippi valley may be considered a mature valley, approaching old age in its lower parts and youth in its upper tributaries, where recent changes have rejuvenated the streams. The rejuvenation has caused many canyons, in which there are falls, like the Great Falls of the Missouri. One of the most noted canyons is that of the Yellowstone, at the head of which are Yellowstone Falls (Fig. 480), located in the lava plateau of Yellowstone National Park. In many places volcanic accidents and mountain uplift have rejuvenated the mountain tributaries. There are numerous instances where the rivers cut across mountain ranges; for example, the Missouri in Montana, and the Arkansas in Colorado, forming the famous Royal Gorge of the Arkansas.

FIG. 481. — Sketch map showing the navigable rivers of United States.

Like the Colorado and Rio Grande, the western tributaries are supplied with abundant water from the mountains, especially in spring, when they become 20 or 30 times as high as at the low water stage of autumn. Only about one ninth of the rainfall is carried across the arid plains, so much are the streams reduced by evaporation. This water is of great value for irrigation, and, by storage, will make the plains still more valuable.

So much sediment is supplied to these rivers, and so much water for carrying it is lost by evaporation and seepage, that the streams

are all muddy. The Platte is so burdened that it is aggrading its bed, and doing it with such rapidity that the river is embarrassed in passing through its own deposits (Fig. 112). The Red River receives its name from the color of its sediment; and the turbid Missouri is often called the "Big Muddy." At their junction, the Mississippi has about as much water as the Missouri; but since it has less sediment, it is able to move down stream that which the Missouri brings.

The Ohio drains part of the Alleghany plateau on one side and of the Central Plains on the other. Since the climate of its valley is humid, with a rainfall of over 40 inches a year, the Ohio carries more water than the Missouri. The water supply varies greatly, being least during summer droughts, when the river may be only 2 or 3 feet deep, and most in spring when the snows are melting. It may then reach a depth of from 50 to 60 feet (Fig. 99).

The Ohio and most of its tributaries occupy mature valleys; but those in the plateau are deep and steep-sided, dissecting the plateau into the rugged condition of early maturity (p. 84). Throughout most of its course the Ohio is bordered by a floodplain, behind which bluffs rise to a height of 200 or 300 feet. This is an excellent farming country, and the valley is easily followed by railways. The river is navigable even above Pittsburg, though in some places rapids have made canals necessary.

The upper Mississippi resembles the Ohio in most important respects. In both cases the valleys have been seriously influenced by the glacier, which has caused rapids and falls. In its headwaters, the Mississippi passes through a series of lakes and swamps of glacial origin.

Below the junction of the Mississippi and Ohio at Cairo, the Mississippi flows in a floodplain which it is building up because it has more sediment than it can carry down the gentle grade. This floodplain, bordered by low bluffs, is about 600 miles long and from 20 to 75 miles wide. Mem-

phis and Vicksburg are situated on the eastern bluff, at points where the river swings against it. Over this immense, fertile floodplain the river swings in a series of meanders, often as much as 5 miles in diameter. These nearly double the length of the lower river.

The river is slowly changing its position in the floodplain, and, now and then, the neck of a meander is cut off and a ring-shaped ox-bow lake is left. There are many such lakes which are slowly being filled with sediment. Floods, seepage from the river, and lack of drainage on the level floodplain cause the abandoned channels, or *bayous*, and other low places, to remain either as lakes or swamps (Fig. 308); the higher parts are drier and make excellent farm land. At times of great flood, when the river may rise from 30 to 50 feet, the water sometimes opens gaps, or *crevasses*, in the levees which men have built to confine the river. Then the water tears away the levees, spreading over the floodplain and doing great damage. It is the deposits made during such inundations that are building up the floodplain.

Sediment, washed from the slopes of the entire Mississippi system, has built a large delta at its mouth (Fig. 105). This is still growing outward, for each year enough sediment is poured into the Gulf to build a pyramid a square mile at the base and 268 feet high. Most of the delta is too low, level, and marshy for habitation, and over it the river flows sluggishly through a series of distributaries. Sediment is constantly being deposited on the river bed, interfering with navigation, especially at the river mouth. To check this, *jetties* or piers have been built at one of the mouths, or *passes*, in order to confine the current and cause it to flow rapidly enough to keep the channel open for large vessels.

Summary. — *The Mississippi, with its many large tributaries, occupies a valley left as a lowland by the greater uplift of the sides. It is, on the whole, mature; but rejuvenation, by volcanic action and by uplift, has occurred in many of its headwaters. The tributaries which cross the arid western plains are supplied with water from*

the mountains, which is of value for irrigation; they bring much sediment. The Ohio and upper Mississippi valleys are mature, have abundant rainfall, and are excellent agricultural regions. They have been affected by glaciation. Below Cairo is a broad floodplain, between bluffs, and farther down a delta, both made of sediment brought by the river. Where dry enough, both are excellent farm land.

207. Smaller Streams of the East. — From the Rio Grande to northern Maine there are a large number of small streams, including the Colorado and Brazos of Texas, the Alabama, James, Potomac, Susquehanna, Delaware, Hudson, and Connecticut. South of the Hudson their lower courses are across the coastal plains, in shallow valleys consequent on the slope of the plains. Sinking of the land has made most of the larger streams navigable in their lower courses. In some cases, especially in the North, where sinking of the land has been greatest, vessels can pass far inland. The importance of this is well illustrated by the Chesapeake, Delaware, and Hudson valleys.

From Alabama northward the headwaters of the large streams are either in or west of the mountains. This fact has been of great importance in many cases, since it has opened water gaps into and across the mountains (pp. 309 and 391). North of New Jersey the streams have all been rejuvenated by the effects of the glacier, and their courses obstructed in places by rapids, falls, and lakes, the importance of which has already been pointed out.

Summary. — *As a result of sinking of the land, many of the small streams of the East are navigable in their lower courses; some furnish openings into and across the Appalachians; and in the North, glaciation has caused many rapids, falls, and lakes.*

208. The St. Lawrence System. — This remarkable river system includes five of the eight largest fresh-water lakes in the world (p. 162). These are connected by short rivers and straits, in several cases containing rapids or falls, including the wonderful Niagara. The lake basins are very deep (p. 161), the bottoms of all but Erie being below sea level.

The St. Lawrence flows out of Lake Ontario, not in a well-

defined valley, but straggling over a low, hilly land, the higher parts of which rise above the water as the so-called Thousand Islands. From this point down to Montreal the river consists of a series of broad, lake-like expanses, with intervening rapids around which canals have been built. The lowest, or the Lachine Rapids, are just above Montreal; and thence, onward to the sea, there is uninterrupted navigation through a broad valley, into which the tide has been admitted by sinking of the land. Below Quebec the valley is a broad bay, and ocean steamers ascend to Montreal. By means of canals around the rapids and falls, large boats may go on to the western end of Lake Superior (p. 311).

The exact preglacial condition of the St. Lawrence system is not yet fully known. It is certainly drowned at one end, and the continuation of its valley, between Nova Scotia and Newfoundland, may still be traced on the sea bottom. When this submerged valley was formed, northeastern North America was more than 1000 feet higher than now, and the mouth of the St. Lawrence was off Newfoundland at the edge of the continental shelf.

The inland continuation of this valley seems to have been not the present St. Lawrence, but Ottawa River, the only large tributary of the St. Lawrence system. Above Montreal the system appears to be made of parts of several systems, united by the effects of glacial erosion, dams of glacial drift, and land tilting. These processes have also transformed parts of the valleys into the deep, boat-shaped basins of the Great Lakes (p. 161). Neither the St. Lawrence above Montreal, nor the rivers and straits that connect the lakes, are in preglacial valleys of large streams.

Notwithstanding the great volume of water, little erosion is being done along most of the St. Lawrence. The explanation of this is that the lakes, and other quiet stretches, rob the water of its sediment, therefore taking away its erosive power. Consequently, though young, most of the St. Lawrence streams flow, not in gorges, but in shallow valleys.

Niagara River, which furnishes the one striking exception

to this, has peculiar conditions. Leaving Lake Erie clear and free from sediment, the broad Niagara loiters along past Buffalo, almost on the surface of the plain (Fig. 483). At only one point in its upper course is there rapid water, where it crosses a ledge of rock near Buffalo. The river divides into two channels around the low Grand Island. The valley is so young and undeveloped that the channel on one side has not been deepened enough to rob the other of its water.

Just above Niagara Falls, 15 miles from Lake Erie, the stream is again divided, this time around Goat Island. Here the flow in each branch quickens, and soon the water is tumbling along tumultuously as a series of violent rapids. Then it drops as a great cataract, 160 feet high, divided by Goat Island into two parts,—the larger, or Horseshoe Fall, on the Canadian side, the smaller, or American Fall, on the American side. For 7 miles below the cataract the river rushes rapidly through a gorge 200 or more feet deep, and 200 or 300 yards wide (Fig. 485). In two parts of the gorge there are decided rapids, and at one point a whirlpool.

The top of the gorge is at the level of the plain over which the river flows from Buffalo to the Falls; and the gorge cut in this plain reveals its rock structure. It is made of nearly horizontal stràta, some hard, some soft, dipping gently southward at the rate of about 35 feet a mile. The upper stratum in the gorge wall is massive limestone (Fig. 482), beneath which is a series of weak shales. It is these strata, also present under the cataract, that make the waterfall possible.

The plain ends toward the north in a steep slope, or escarpment (Fig. 485), faced by a plain about 200 feet lower. Emerging from its gorge at this escarpment, the river flows quietly over the lower plain to Lake Ontario.

An enormous quantity of water, estimated at 167,000,000 gallons a minute, falls over the Niagara limestone (Fig. 482), which forms the crest of the Falls. The underlying shales are being removed by the swirl of waters, and by

the grinding against them of great blocks of fallen limestone, by a kind of pot-hole action (p. 54). This undermines the limestone, causing huge blocks to occasionally break off, slowly changing the outline of the cataract.

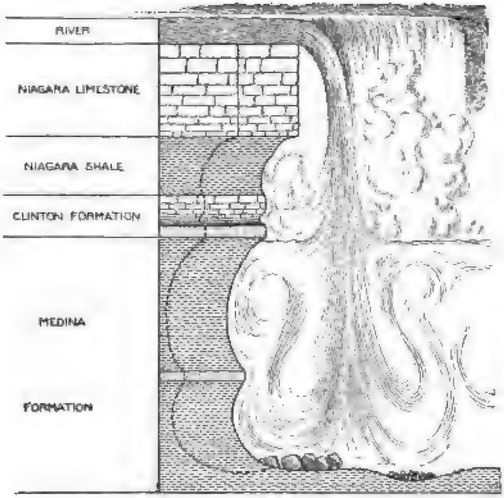

FIG. 482. — To illustrate the undercutting in progress at Niagara (modification of Gilbert's diagram).

There is too little water in the American Fall for such results; instead, the fallen blocks of limestone protect this fall from recession. Records kept since 1842 show that, while the Horseshoe Fall has receded at the rate of about five feet a year, the outline of the American Fall has scarcely changed. Long before the cataract has receded to Lake Erie, the southward dip of the shales will have carried them so far into the ground that there will no longer be an opportunity for the river to undermine the limestone. Then the waterfall will disappear.

There is clear evidence that when the ice sheet permitted Lake Erie to flow over the plain toward Ontario, the Niagara cataract was born, falling over the edge of the escarpment. Since then the cataract has receded for seven miles, making the gorge. When the cutting of the gorge first began, the river occupied a broad valley on the upper plain, similar to the present valley above Goat Island. The river gravels and banks made at that time may still be clearly seen on the plain, 200 feet or more

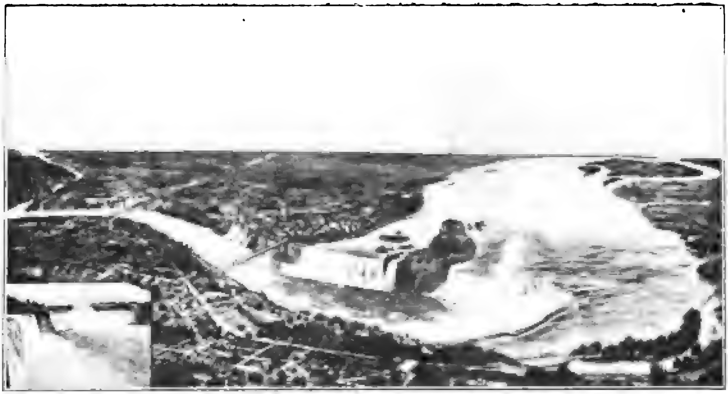

FIG. 483. — Bird's-eye view of Niagara River. Contrast the broad, shallow upper valley with the narrow, deep gorge below the falls.

FIG. 484. — The water escaping here is a small portion of that used for power at Niagara Falls. Yet only a very minute portion of the enormous power available is now used.

FIG. 485. — Relief map of Niagara River. Notice the broad, shallow, upper valley; the falls; the gorge; the whirlpool; the lower shallow valley; the escarpment separating the two plains; and the depression leading from the whirlpool to St. Davids, marking the site of the buried gorge which causes the whirlpool. (Model by E. E. Howell, Washington, D.C.)

above the present river. The gorge could not have existed then. Another proof that the gorge has been cut by river action is the existence of an abandoned fall, similar to the American Fall, at Foster Flats, more than halfway down the gorge.

As the cataract receded, it discovered a buried valley beneath the glacial drift; and where this buried valley leaves the gorge, at the whirlpool, there is a break in the otherwise continuous rock wall of the gorge. The removal of the glacial drift that filled this buried valley has formed the elbow in which the whirlpool is situated (Fig. 485).

It was formerly thought that Niagara gave a basis for telling the time in years since the close of the Glacial Period. Three important facts are known: (1) the length of the gorge; (2) the present rate of retreat of the cataract (five feet a year); (3) the cataract began as the ice was leaving. It therefore seemed simple to divide the distance by the present rate; but later studies show that there are many causes for variation in the rate of retreat, of which the following are most important: (1) the limestone is thinner at the northern end; (2) the time required to remove the loose drift in the buried gorge is unknown; (3) the volume of water has varied; indeed, at one time Niagara received the waters of Lake Erie only (Figs. 280, 281). Since it is impossible to tell just how much these variations have influenced the rate of retreat, the time that Niagara has taken to cut its gorge is not known positively; but there is reason for believing it to have been between 5000 and 10,000 years.

Summary. — *The St. Lawrence system is an immature river system made by the union, largely through glacial action, of parts of a number of rivers. It consists of* (1) *a lower drowned portion;* (2) *a middle section with a series of quiet, lake-like stretches and intervening rapids; and* (3) *an upper portion of great lakes, with connecting straits and rivers, interrupted by rapids and falls. Little erosion is being accomplished because the lakes rob the water of sediment for cutting-tools. Niagara is an exception to this because of the existence*

of weak shales beneath a massive limestone. At the Horseshoe Fall the removal of these shales is causing the cataract to retreat upstream, and there is good proof that it has receded through the seven miles of the gorge, requiring probably somewhere between 5000 and 10,000 years for the work, which began at the close of the Glacial Period.

TOPICAL OUTLINE AND REVIEW QUESTIONS.

TOPICAL OUTLINE. — 201. **The Columbia.** — Climate; length; area; two large branches; valleys in lava plateau; effect of these canyons; lower valley, — crossing mountains, navigation, fishing.

202. **The Sacramento.** — Position; outlet; size; large tributaries; navigation; small mountain tributaries; uses of water.

203. **The Colorado.** — Source of water; size; inclosing plateau; canyon valleys; lower course; Grand Canyon, — barrier, difficulties of passage, rapids, canyon walls; tributaries; young plateau.

204. **The Great Basin.** — Area; situation; minor basins; Basin Ranges; rainfall; streams; irrigation; former lakes.

205. **The Rio Grande.** — Compare with Colorado; irrigation; tributaries; variation in volume; sediment load; delta; navigation.

206. **The Mississippi System.** — (a) *The system:* length; area; principal tributaries; navigation. (b) *The valley:* origin of lowland; ancient sea; mature condition; rejuvenation; mountain gorges. (c) *Western tributaries:* water supply; floods; loss of water; irrigation; sediment, — cause, Platte, Red, Missouri. (d) *Ohio:* rainfall; floods; mature valley; floodplains; farming; navigation. (e) *Glacial influence:* rapids and falls; upper Mississippi. (f) *Floodplain of lower Mississippi:* cause; area; bluffs; meanders; changes in river position; lakes, bayous, and swamps; floods; levees; deposits. (g) *Delta:* outward growth; swampy surface; distributaries; jetties; passes.

207. **Smaller Streams of the East.** — Names of principal ones; condition on Coastal Plain; effect of land sinking; pathways across mountains; effects of glacier.

208. **The St. Lawrence System.** — (a) *Description:* lakes; connection of lakes; Thousand Islands; rapids below the lakes; drowned lower course; navigation. (b) *Preglacial condition:* submerged valley; former elevation of continent; Ottawa River; effect of glacier on river; on lakes. (c) *Erosion:* absence of sediment; effect on valley form. (d) *Niagara:* near Buffalo; Grand Island; Goat Island; rapids; two falls; gorge; upper plain; rocks in gorge wall; escarpment; condition below escarpment. (e) *Recession of falls:* cause of retreat; condition in American Fall; rate in Horseshoe Fall; future of falls. (f) *History of Niagara:*

birth of falls; cause of gorge; proofs of this; cause of whirlpool. (g) *Age of gorge:* facts known; causes for variation; probable age.

REVIEW QUESTIONS.—201. What is the situation of the Columbia? Its length and drainage area? What are the two great branches? What is the condition in the upper part? In the lower part?

202. Describe the Sacramento Valley; its situation; lower portion; size; large branches; small tributaries; uses of water.

203. State the general features of the Colorado: source of water; size; canyons; lower portion. Describe the Grand Canyon. Why are there few tributaries? What is the condition between them?

204. What are the surface features of the Great Basin? What is the climate? What effects has this on the region?

205. Compare the Rio Grande with the Colorado. How do they differ? Why is there so much irrigation? How does the volume vary? What is the condition in the lower course?

206. What is the size of the Mississippi and its largest tributaries? What is the origin and form of its valley? What is the condition in the headwaters? What is the condition of the water supply in the western tributaries? Of the sediment? What are the principal characteristics of the Ohio? What effects have been produced by glaciation? What are the characteristics of the floodplain: area; bluffs; meanders; floods; swamps; farm land; levees? What is the condition on the delta?

207. Name the principal small streams in the East. What are their main characteristics? In what ways are they important?

208. What is the general condition of the system? What is the condition below Lake Ontario? What was the preglacial condition? Why is there little erosion? Describe Niagara River. What is the rock structure of the gorge walls? How, and at what rate, is the cataract caused to recede? What will happen as the fall recedes farther? What proofs are there that the gorge was formed by the river? Explain the whirlpool. What is known of the length of postglacial time?

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CHAPTER XVII.

DISTRIBUTION OF PLANTS.

CONDITIONS INFLUENCING PLANT LIFE.

209. Importance of Air. — Without air, both plants and animals die. Carbon dioxide from the air is taken into plant cells and changed to carbon and oxygen, the carbon being built into the tissues. A large portion of the plant tissue is made of carbon, supplied mainly by the air.

Air is present everywhere on the earth's surface, even in soil and water (p. 180); therefore, as far as this vital substance is concerned, it is possible for plants to be present on every part of the earth's surface. The fact that there are some places where plants are absent, — for example, underground, in the deep sea, and in central Greenland, — is proof that there are other things of vital importance.

Summary. — *Air is of vital importance to plants, supplying most of the carbon, of which a large part of plant tissues is made.*

210. Importance of Temperature. — Plant activity is impossible where the temperature is below freezing, for then the liquid parts are frozen and cannot move about. In the ice-covered interior of Greenland, therefore, where the temperature is always below freezing, all plant life is absent. Many plants are not injured by being frozen for part of the year, but are able to resume growth when the frost is gone.

All plants, even the lowest forms of bacteria, are killed when subjected for a short time to temperatures near the boiling point. This is because such heat causes changes in their tissues which destroy their power of action.

FIG. 486. — A view in Greenland, showing the prevailing bare rock surface with lichens clinging to it. Small areas of soil are present in the depressions between the ledges. There is a group of Eskimo women in the middle of the picture.

Fig. 487. — Open forest of the East late in the fall. Notice how short the lower limbs have become because of the lack of light when in full leaf.

Fig. 488. — A view in the forest of large trees in western Washington. **A rank growth of ferns thrives in the forest shade.**

Fig. 489. — Negro woman gardening in the tropical zone.

Fig. 490. — A banana tree in the tropical zone.

Fig. 491. — A view on the savanna of Africa, a negro village in the foreground.

Fig. 492. — A banyan tree, in tropical India, with roots descending from the lower branches.

Fig. 493. — A cocoanut palm.

Fig. 494. — The dense tangle of the tropical forest. The opening in the middle is where a path extends through the forest.

A low form of plant lives on the lower parts of the Greenland glacier, being frozen all the year excepting a few weeks in summer, when it lives in ice-cold water. Certain lowly plants thrive in the hot springs of Yellowstone Park, whose water, though hot enough to destroy most plants, is not up to the boiling point. These instances show that plants may become adapted to very unfavorable surroundings. They could not live under any other conditions; yet no other plants could live where they do.

Summary. — *Even the lowest plants are unable to live where the temperature always remains below freezing, or where it rises to the boiling point even for a short time; but many survive a period of freezing, and some live in the water of hot springs.*

211. Importance of Sunlight. — Sunlight is also of vital importance to plants, for by its aid the green cells change carbon dioxide to carbon and oxygen. The branches and leaves of plants are, therefore, arranged to secure air and sunlight; and many forest trees lose their lower limbs (Fig. 487), or even die for lack of light.

Plants growing in dark places, like potatoes sprouting in a cellar, are weak and tender, and their lack of color shows the absence of the important chlorophyl of the green cells. It is because of absence of sunlight that no plant life exists on the ocean bottom. Yet some low plants do grow in darkness. For example, a weird-looking, pale white fungus lives in coal mines and caverns, where no ray of sunlight has ever entered. This is another instance of how life may adapt itself to very unfavorable surroundings.

Summary. — *Light is needed for the change of carbon dioxide to carbon and oxygen; therefore very few plants live in dark places.*

212. Importance of Water. — No plant can live without water; for it circulates among the tissues, bearing food and other materials from one portion to another, as man's blood does. In trees this plant blood is commonly called sap; and when it rises in spring, the plant awakens from its long winter sleep and bursts into leaf and flower.

Plants living in water have a supply ever at hand; but most land plants obtain water from the soil, though in damp tropical forests some species secure enough from the air. If the soil dries, plants wither; but in arid and desert regions plants have fitted themselves to survive long periods of drought.

Summary. — *Water, needed for the sap of plants, is obtained from the water, air, and soil.*

213. Importance of Soil. — Soil is not necessary to plant life. Water plants, both fresh and salt, may secure all necessary substances from the surrounding water. Thus many float freely about, while others have roots solely for the purpose of anchoring themselves in place. Some land plants, called *epiphytes*, are also able to live without roots, securing all necessary substances from the air. The great majority of land plants, however, depend on the soil for most of their water, part of their food, and for anchorage.

The plant food in the soil is of such importance that, where it is almost absent, as in sand, the soil is said to be sterile, and most species of plants do not flourish. Plants remove so much mineral matter from the soil that, where crops are raised year after year, it is necessary to use a fertilizer to replenish the plant food.

Plants are adapted to different kinds of soils, some needing loose, open soil, others compact, clayey soil; some requiring one kind of plant food, others another. A very little study of wild flowers or crops shows that plant life varies with the soil.

Summary. — *Most land plants depend on soil for water, mineral food, and anchorage; but some land, and most water plants do not need soil. Land plants differ greatly according to the soil.*

214. Importance of Gravity. — Plants send their roots into the ground, seeking water which gravity has drawn into the earth. Seeking sunlight, they send their stems straight up from the ground. This is the easiest way for them to resist the pull of gravity; if they were inclined, for example, they would fall far more easily. To aid in withstanding the pull of gravity and the force of the wind, large plants build strong, woody trunks

and branches. Water plants, on the other hand, are usually weak, loose-textured, and flabby, because they live in a denser medium, which buoys them up so that they do not need great strength to resist gravity. Such plants as sea weeds, which are exposed to waves, require a tougher texture.

Summary. — *The influence of gravity causes plants to send roots downward, and strong, woody stems straight upward.*

DISTRIBUTION OF PLANTS.

From what has been said, it is evident that the distribution of plants is influenced by surrounding conditions; and since there is much difference in the climate and soil of the earth, there are great differences in plant life.

215. Influence of Climate. — Climate is the greatest factor in determining the distribution of plants. Some species, especially the more lowly, have a wide distribution and are adapted to many climates; but most plants of higher orders are fitted for only one set of surroundings. For example, sugar cane requires a warm, damp climate beyond the reach of frost; cotton grows best in a slightly cooler, though still warm, sunny climate; corn, though requiring a long, warm summer, grows much farther north than cotton; and wheat may be raised in a climate too cold for corn. Wild plants are limited in distribution in similar ways.

There are, therefore, zones of plant life similar to the zones of temperature. An Arctic plant will die amid tropical heat as certainly as a tropical plant will perish when exposed to the frosts of a temperate winter. The plant life, or *flora*, of moist climates also differs from that of arid climates. These differences may be best understood by studying the plant life in several climatic zones.

Summary. — *There are zones of plant life, similar to those of climate; for, while some lowly plants are adapted to several zones, higher plants are usually fitted for life in only one.*

216. Arctic Flora. — In the Arctic, plants spring up as soon as the frost melts, and quickly flower and bear fruit, for the season is short. Lichens in great variety cling to the rocks (Fig. 486), and many mosses and water-loving plants live in the swampy soil. There are grasses, numerous flowering plants, and species with woody tissue, including dwarf willows and birches — true trees in all respects but size. They cling close to the ground, not rising high because it is important that the first snows shall cover and protect them from the cold blasts of winter. The short growing season, and the bitter winter cold, prohibit the growth of trees.

For more than two thirds of the year, while the temperature is below the freezing point, plant life is dormant; but in the brief summer season the sap flows, the plants grow, and the tundra is covered with a mat of green, dotted with bits of color. Yet only the surface soil is free from ice, for at depths greater than two or three feet frost is ever present.

Summary. — *In the short Arctic summer, when frost melts from the upper layers of soil, plants grow rapidly, clinging close to the ground to secure protection from the winter cold.*

217. Temperate Flora. — Near the margin of the temperate zone in both hemispheres is a timber line of low, scraggy trees struggling for existence amid unfavorable surroundings. The trees are all of hardy varieties, some *evergreen*, others *deciduous*, that is, shedding their leaves in autumn. The evergreens have tough, needle-like leaves which withstand the cold of winter, falling only in spring, when new ones take their place. Among the common evergreens are spruce, hemlock, balsam, fir, and pine.

In the warmer part of the temperate zone deciduous trees increase in number and variety, including the beech, birch, maple, oak, elm, chestnut, hickory, ash, walnut, and many other species. There are also many fruit trees such as apple, pear, peach, and cherry. These trees, which spring into leaf

and blossom in spring, and bear fruit in summer and fall, are checked by the autumn frosts. Their sap then ceases to flow, the leaves assume brilliant colors, then fall, and for a time the trees are dormant. They lay aside their activity during the season when active life is impossible.

Other plants, called *perennials*, die down to the ground when the frosts come, growing again in spring from roots or bulbs in which nourishment has been stored during the active season. Still others, called *annuals*, die completely in the fall, leaving only seeds to reproduce their species when growth is again possible.

The flora of the temperate zone varies greatly according to temperature, exposure, humidity, and soil. There are places where trees do not grow, for example on dry plains, and on prairies (p. 77), on which, however, grasses and many flowering plants grow luxuriantly. In other places tree growth is scrubby and of few kinds, as in sandy soils which support only pines and oaks. On the other hand, there are places where the climate and soil favor a luxuriant forest growth. Every part of the land is occupied to its fullest extent by plants fitted to live there.

One of the most remarkable instances of plant growth is in the region of "big trees" on the west coast of United States (Fig. 488). There, a fertile soil, a damp, equable climate, and absence of strong winds encourage the growth of enormous trees. Only in southeastern Australia, where similar conditions exist, are there trees rivaling these in size. Some of the California trees are 300 feet high, 40 feet in diameter, and fully 2000 years old.

Summary. — *Near the frigid zone, tree growth ceases, the timber line being marked by scraggy trees, both evergreen and deciduous. Deciduous trees increase in number and variety in the warmer parts of the temperate zone. Plants are adapted to the winter season in several ways: by suspending activity, by dying down to the ground, and by dying completely, leaving seeds to continue the species. There are many differences in flora according to temperature, exposure, humidity, and soil.*

218. Tropical Flora. — In the warm, humid portions of the temperate zones, near the tropics, the abundant and varied flora is more like that of the tropical than of the cool temperate zone. It is therefore called subtropical. Both here and in the humid tropical zone the warmth and dampness favor the luxuriant growth of a great variety of species. Among these are long-leaved pines, broad-leaved evergreens, palmettoes, and palms (Figs. 493, 499); also such valuable trees as the teak, mahogany, rosewood, cocoa, banana (Fig. 490), and the rubber tree.

There is no one season of growth, and no dormant period; blossoms may appear at any time, and there is no period when all the leaves fall. The trees grow to great size, and, in their struggle for light, to great height. The undergrowth is dense (Fig. 494), trailing vines hang from the limbs, and epiphytes abound.

Summary. — *The subtropical flora of the warm temperate zone and the tropical flora are quite alike in variety and luxuriance of growth, and in the absence of a dormant period.*

219. Flora of Savannas and Steppes (pp. 283, 285). — In regions where there is a season of drought, as in the savannas (Fig. 491) and steppes, trees cannot grow excepting along the streams. Many grasses and flowering plants bridge over the period of drought by means of roots, bulbs, and seeds, springing into life when the rains come, as plants of the cool temperate zone do at the close of winter. Therefore, such regions are excellent pasture lands.

Summary. — *Regions having a period of drought are treeless; but annuals and perennials thrive, making these good pasture lands.*

220. Desert Flora. — In deserts there is too little moisture for a great number of individuals. Therefore, instead of having a complete cover of vegetation, the desert is scantily clothed with a scattered flora (Figs. 154, 498). Every possible effort is made by the plants to secure and retain enough moisture for life. Some plants have enormous roots, extending deep into the ground and spreading far about in search

of water; the mesquite, for example, has several times as much woody matter below ground as above it. Water is stored in these roots for use during the long droughts.

Desert plants have many devices for existence amid their unfavorable surroundings. In order that the surface for evaporation may be reduced to a minimum, no more leaves are produced than are absolutely necessary; and in many cases the leaves are small and tough, or are even reduced to spines. In the cacti (Figs. 495–497), which are especially well fitted for desert life, water is stored in the tissues; there are no true leaves; and the plant has a hard, shiny, varnished surface, through which evaporation is almost impossible. Some species are globular in form, thus exposing the least possible surface to evaporation; and the sharp, irritating spines protect them from many kinds of animals which might otherwise devour them. Many desert plants repel plant-eating animals, as the common sage brush does, whose tough, pale green leaves have a disagreeable odor and taste.

Sunlight, temperature, and much of the desert soil are favorable to abundant plant life; but water is lacking. It is remarkable that any plants should be able to adapt themselves to life where rain comes at intervals of months or even years. That this is the only unfavorable condition is proved where oases exist in the desert, or where irrigation is introduced. Then the watered desert supports plant life in great variety and luxuriance.

Summary. — *Because of lack of water, the desert flora is scattered and many devices are adopted to store enough to last through the periods of drought. The luxuriance of growth on oases and irrigated sections proves that water is all that is lacking for plant life.*

221. Mountain Flora. — In every zone the flora varies with altitude. A temperate flora is found on mountain slopes in the tropical zone; and an Arctic flora on mountain tops in temperate zones. Thus, species growing in Labrador and Greenland are also found on the top of Mt. Washington.

Even in the tropical zone there is a line, the *timber line* (p. 96), above which it is too cold for trees to grow. This line, marked

by stunted, scrubby trees, is not regular, but extends highest on those slopes which furnish most protection from winds or longer exposure to the sun (Figs. 158, 161, 166). Above the timber line, wherever there is soil, the surface is covered with low bushes and flowering plants (Fig. 181), forming the mountain or *Alpine flora*, famed for the variety and beauty of its flowers. The cool summer air, damp soil, and long, cold winters resemble conditions in the Arctic; but there is more sunlight.

Mountains and high plateaus rising from desert lands may have rainfall enough for forest growth. On the lower slopes the trees are stunted, scrawny, and scattered, showing the struggle with drought; but higher up the forest becomes dense. If the mountains are high, tree growth may be checked above by cold, as well as below by drought.

Summary.— *Because of changes in temperature, the flora varies with altitude. On mountain slopes the forest disappears, and in the upper portion is replaced by the Alpine flora.*

222. Water Plants.— Wherever conditions favor, both in salt (p. 195) and fresh water, there is a varied flora, some species floating on the surface, others anchored, and still others having true roots. Lower forms, such as algæ and mosses, are especially adapted to life in water; but higher forms, even trees, are not absent. Rushes, reeds, mosses, and lilies are among the common fresh-water and swamp plants; and among trees the cypress, black gum, willow, and mangrove are common, the latter living in salt water (Fig. 379).

Most trees die if their roots are submerged, because air is cut off; but water-loving trees have special provision for securing the necessary air. For example, mangrove roots start from above the water surface, and even from the lower limbs; and knobs, or knees, grow upward from cypress roots till they project above the water surface (Fig. 307).

Summary.—*Plant life is abundant both in fresh and salt water, the lower forms being especially common, though even some trees are adapted to life in water.*

FIG. 495. — The prickly pear, one of the spiny cacti.

FIG. 496. — Giant cacti of southwestern United States. The man on the right gives an idea of the size of this plant.

FIG. 497. — A group of cacti, showing rounded forms and spiny surfaces.

FIG. 498. — A view on the desert of southwestern United States. Note the general barrenness, with vegetation here and there in clusters.

Fig. 499. — A cluster of palms near the Pyramids in the desert region of Egypt.

FIG. 500. — Plant life in the water. Describe the vegetation in this picture.

223. Means of Distribution. — Since the land is so well occupied that it is difficult for a new plant to gain a foothold, it is necessary that adequate provision be made to insure the spread of plants. Seeds are the principal means of insuring this spread. It is necessary to produce far more seeds than can possibly find a chance to grow, for some are eaten, some decay, some fall in impossible positions, and some that sprout find conditions so unfavorable that they die.

In order that they may have every chance for a start in life, seeds are provided with many ingenious devices to aid in their spread. Some are so light that they are drifted about by the slightest breeze; some, like the maple, have wing-like projections that catch the wind; some, like dandelion seeds, have a light, feathery float; some, like the many burs, have hooks that catch upon the fur of animals; and some, like the apple or peach, are covered with an edible coat. Animals eat these fruits, often depositing the hard, protected seeds far away from the parent plant.

The wind and animals are the two most important agencies in spreading plants. Because light seeds are so easily carried by the wind, light-seeded plants are most widely distributed. Rivers also float seeds and plants from one place to another, and ocean currents may drift them even to oceanic islands. Man has become an important agent in distributing plants over the earth. He carries cultivated plants from one region to another, and also distributes many weeds. In this way the Canada thistle and the white field daisy, now such common weeds, were brought to United States.

Summary. — *Plants are distributed mainly by seeds; and since many seeds are destroyed, far more are produced than could possibly grow. They are largely distributed by wind and by animals, with the aid of many interesting devices; also by rivers, ocean currents, and by man. Light-seeded plants are most easily and widely distributed.*

224. Barriers to the Spread of Plants. — If seeds from the land fall upon water, they do not grow unless drifted ashore.

In other words, water is a barrier to their spread; it is, in fact, the greatest barrier to the distribution of land plants, especially if it is a large body like the ocean. It would be under very rare conditions, for example, that even a single seed could be carried from South America to Africa by winds, currents, or birds.

Yet even the ocean is not an absolute barrier, and plants from the mainland are found on all oceanic islands. Only the seeds of certain plants find their way there, however, and island floras are, therefore, far less varied than those of the mainland. The most common plants are those with seeds so light that they are easily carried by wind; or those that birds eat and carry; or those, like the cocoanut, that will float for a long time in the sea.

Deserts are barriers because no plants, except those adapted to desert conditions, can spread across them, unless carried entirely over. A tropical forest is an equally good barrier for plants that are adapted to desert life. Mountain chains are also barriers, because plants at their base will not spread into the cold climates above; but gaps or passes often are pathways for the spread of plants across mountains. The wind, although an aid to distribution in one direction, is a very important barrier to spread in the opposite direction. For this reason European plants are not likely to reach America against the west winds; but these winds aid American plants in their spread to Europe. Ocean currents and birds also aid in the same direction.

Summary. — *The ocean is the greatest barrier to the spread of land plants; but even this is not an absolute barrier, for plants whose seeds can be carried by winds, birds, and ocean currents are found even on remote oceanic islands. Deserts and mountains are also barriers; and wind checks the spread of plants against it.*

225. Variation in Plants. — Among plants there is a struggle for air, food, light, water, and opportunity to reproduce their kind. This struggle is going on everywhere; it may be seen in a neglected flower garden, where weeds

spring up from chance seeds, and, being better fitted for the struggle than carefully nourished, cultivated plants, take complete possession of the garden. They tower above the cultivated plants, shutting out light and robbing the roots of water and mineral food. Under such conditions the cultivated flowers are small and imperfect.

Because of this struggle for existence plants are steadily changing; and those that best fit themselves for the struggle have the best chance of surviving and spreading. This has been called the survival of the fittest. In this struggle plants have fitted themselves to survive the cold of winter; to live amid the unfavorable surroundings of the desert; in fact, to grow among most conditions on the earth's surface. Fossils in the rocks prove that similar change, or *evolution*, has been in progress for ages.

The following will serve as illustrations of how plants are forced to vary with environment, that is, to undergo evolution. A mountain, rising above the timber line and bearing an Alpine flora, is slowly worn down to the low, hilly condition of maturity. If the plants cannot adapt themselves to the changes in climate, slope, and soil, they must give place to forms better fitted.

The effect of the ice sheet offers another illustration. As it advanced over the land, it either drove out or destroyed all life; and near its margin the climate was changed from warm to cold, so that the plants living there either had to adapt themselves to the changes or die. When the glacier melted away a new soil was uncovered, and a struggle ensued for possession of it. The light-seeded plants came first, and even now the heavy-seeded plants are slowly advancing northward. These changing conditions have forced some species to evolve new characteristics. The history of plant life during past ages has been a succession of changes by which plants have become better adapted to their surroundings.

Plants undergo many changes as a result of their relation to animals. Since animals depend on plants for food, some means must be provided to prevent complete destruction. For this purpose hard wood, thorns, bitter taste, and other means have been

evolved. Many plants make use of animals, for example, in spreading seeds and in distributing pollen. Honey, odor, color, and many interesting forms of flowers are provided to attract insects and to secure from them the service of carrying the pollen.

Man is now one of the most important agents in changing plants. By giving them better care, with plenty of light and food, and removing weeds, thus relieving them from the struggle with other plants, he is able to secure far larger seeds and fruits than grow naturally. For example, a good apple tree, left to itself, soon has to struggle with weeds and bushes, and its fruit becomes sour or bitter. By much care and many devices, men are constantly producing new varieties of flowers and fruit. This is done by forcing evolution to work more rapidly than it does naturally; and, in this way, changes may be caused in a few years which, by natural processes, might require centuries.

Summary. — *The struggle of plants to adapt themselves to their surroundings, that is, the struggle for existence, which is everywhere and always in progress, causes weaker forms to die out and the survival of the fittest. Slow changes in climate or in land form cause variation, or evolution, in plants. Changes are also brought about for the purpose of protection from, or making use of, animals; and man is now causing changes at a far more rapid rate than evolution naturally works.*

226. Plants of Value to Man. — Man, like other members of the animal kingdom, depends for food upon plants. Even though he may feed on meat, the animal from which it came has received its nourishment, directly or indirectly, from plants. In a warm climate such an abundance of plant food is easily obtained, at all seasons, that there is little need of special provision. But in climates with a dry or cold season it is highly important to provide a store of food for use during the unfavorable season. This need has led to the cultivation of food plants.

The portions of plants most useful for food are those in which nourishment has been stored to aid in the propagation of the species. Among these are seeds, like wheat; fruits, like bananas; bulbs, like onions; and tubers, like potatoes. Some of the food plants, like dates, cocoanuts, bread fruit, and bananas, used extensively in warm climates, have been changed very little.

Others, especially those cultivated in the temperate zones, have been so improved that they are now quite unlike the original plants which savage man first ate. The most important of these, including the orange, apple, pear, peach, cherry, grape, wheat, barley, oats, and rye, have been carried to many parts of the world. In the case of many, the source is not now known; but most of our food plants apparently came from Asia, where they have been cultivated for thousands of years. America has added the potato, tomato, pumpkin, and Indian corn, or maize, as well as tobacco.

Plants also supply us with materials for shelter, clothing, medicine, and other purposes. Cotton (Fig. 503) is the most valuable of the several plant fibers used for clothing. In all lands wood is used both for shelter and for ornamental purposes. Sugar (Fig. 501), coffee, tea (Fig. 502), cocoa, vanilla, tobacco, quinine, and many other plant substances, not of vital importance, are much used by men. The list of valuable plants is a very long one.

For food and clothing, plants are carefully cultivated; but for shelter it has been customary to depend upon the forest, which grows without care. In parts of Europe, however, so much of the forest has been removed that it has become necessary to cultivate even the forests, planting the trees, weeding out the poor ones, and carrying on lumbering with great care. The time has now arrived in America, when the forest needs to be cultivated. Accordingly, both the national and state governments have set aside large tracts as forest reservations. A division of the national government is known as the Bureau of Forestry, and a

number of states have forestry bureaus. There are also schools of forestry, like those at Cornell, Yale, Wisconsin, and Michigan universities, where men are scientifically trained to be foresters.

Summary. — *Man and all animals rely for their food, either directly or indirectly, on the vegetable kingdom. In regions with a cold or dry season, it is necessary to provide food for the unfavorable season, and this has led to the cultivation and improvement of a number of plants for their seeds, fruits, bulbs, and tubers. Many plants are also used to supply materials for clothing and shelter; and now even forests are cared for by methods of scientific forestry.*

Topical Outline, Review Questions, and Suggestions.

Topical Outline. — 209. **Importance of Air.** — Carbon dioxide; carbon in plant tissues; extent of air; places where plants are absent.

210. **Importance of Temperature.** — Effect of freezing; temporary freezing; effect of boiling; plants on Greenland ice; in hot springs.

211. **Importance of Sunlight.** — Its use; plant life in dark places.

212. **Importance of Water.** — Use of water; sap; source of water.

213. **Importance of Soil.** — Water plants; epiphytes; dependence of most land plants on soil; plant food; effect of differences in soil.

214. **Importance of Gravity.** — Roots; stems; wood; water plants.

215. **Influence of Climate.** — Lowly plants; higher plants; illustrations; effect of temperature; of moisture.

216. **Arctic Flora.** — Rapid growth; kinds of plants; clinging to ground; winter; summer.

217. **Temperate Flora.** — Timber line near Arctic; evergreen trees; kinds; deciduous trees; kinds; dormant condition in winter; perennial plants; annuals; treeless regions; sandy soils; "big trees."

218. **Tropical Flora.** — Subtropical flora; tropical trees; the forest.

219. **Flora of Savannas and Steppes.** — Drought; plant growth.

220. **Desert Flora.** — Scattered growth; large roots; nature of leaves; cacti; plants with disagreeable taste; proof that water alone is lacking.

221. **Mountain Flora.** — Tropical zone; temperate zone; timber line; Alpine flora; flora of desert highlands.

222. **Water Plants.** — Position; kinds; adaptation of trees.

223. **Means of Distribution.** — Abundance of seeds; devices for their spread; distribution — wind, animals, rivers, ocean currents, man.

224. **Barriers to the Spread of Plants.** — The ocean barrier; ocean-island flora; desert barrier; mountain barrier; wind barrier.

225. **Variation in Plants.** — Cause of struggle; illustration; struggle for existence; survival of the fittest; evolution; illustrations of causes for evolution; evolution in past; securing protection from animals; making use of animals; effect of man on evolution.

226. **Plants of Value to Man.** — Dependence on plants; plant food in warm climates; in places with an unfavorable season; parts of plants used; improvement; important food plants; source of food plants; American food plants; plants used for other purposes; care of the forest.

Review Questions. — 209. What do plants take from the air? Where are plants absent?

210. What is the effect of cold? Of heat? Give an illustration of adaptation of plants to cold. To heat.

211. Of what importance is sunlight? What effect has darkness?

212. Of what importance is water? How is it obtained?

213. What plants are not dependent on soil? Of what importance is soil to land plants? Why is fertilizer used?

214. State the effects of gravity on land plants. On water plants.

215. How are plants influenced by climate? Give illustrations.

216. State the peculiarities of plant life in the Arctic.

217. What are the conditions of tree growth near the frigid zone? In the warmer temperate zone? In what ways are plants adapted to winter conditions? How does the flora of the temperate zone vary? What conditions favor the "big trees"?

218. What is the subtropical flora? Name some of the tropical trees. What are the characteristics of the tropical forest?

219. What are the characteristics of the flora of savannas and steppes?

220. How are desert plants fitted to survive periods of drought? How are they protected from animals? What do the oases prove?

221. What changes occur in the flora of mountains? Compare Alpine and Arctic flora. What are the conditions on highlands in deserts?

222. What kinds of plants thrive in water? How are trees adapted to water life?

223. Why are so many seeds produced? What devices are there to aid in the spread of seeds? By what agencies are plants spread?

224. Why is water a barrier? How is it certain that the ocean is not an absolute barrier? What other barriers are there?

225. For what are plants struggling? Give an illustration. What is the result of the struggle? What do fossils prove? Give two illustrations of how changes on the earth may influence evolution. What is the effect of the relation between plants and animals? How is man influencing evolution?

226. How is man dependent on plants? What is the condition in

warm climates? In regions with cold or dry seasons? What parts of plants are used for food? What effect has cultivation had? Where have the cultivated plants come from? For what other purposes are plants used? What is now being done with the forest?

SUGGESTIONS. — (1) Place a hardy plant, such as moss, in boiling water for a few minutes, and plant it to see if it will grow again. (2) Freeze the same plant for a night and see if it will grow. Freeze a delicate plant, for example a geranium, and see if it will continue to grow. (3) Place a plant, say a geranium, in the cellar and let it grow for a few weeks, and note the change. (4) Leave a plant in its pot without water and see if it grows. Keep water up to the top of the earth (a swamp) and see if it kills the plant. Get a cactus and see if it will live in dry soil. Study the cactus. (5) Using the same kind of seed, try growing plants in several different kinds of soil, — sandy, fertile loam, etc., and see which thrives best. (6) Try to burn ash. Perhaps the teacher of chemistry can suggest an experiment to prove that there is mineral matter in ash. (7) Put a plant in a pot, inclining it at an angle to the surface. Will it keep on growing in that direction? (8) Collect and study seeds to see what devices they use for distribution. (9) Plant a bean in a flower pot in absolutely dry earth (a desert). Does it sprout? Place one in a jar of water. Does it grow after it has used up the nourishment in the seed? This illustrates why deserts and water are barriers. (10) Study the flora of your vicinity to see if the plants vary in kind from one soil, or exposure, to another. If there is a swamp, find how the swamp plants are different from those on dry slopes. (11) What crops are raised in your vicinity? What crops cannot be raised? Why? Is there a difference in crops according to the soil? (12) Make a list of plants valuable to man, their principal uses, and the localities from which they come. Let each student make a list, then combine it for the use of the whole class.

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FIG. 501. — Cutting sugar cane in Louisiana.

FIG. 502. — Picking tea in India.

Fig. 503. — Picking cotton in southern United States.

Fig. 504. — A pineapple field in the Hawaiian Islands.

CHAPTER XVIII.

DISTRIBUTION OF ANIMALS.

227. Influence of Surroundings. — Plants and animals are alike in being dependent for life on their surroundings. Like plants, all animals, even those on the sea bottom, need air to breathe; all require water for their blood and tissues; and for all it is necessary that the temperature shall be neither too high nor too low. Temperatures near the boiling point, or long continued below the freezing point, are fatal to animal tissues. Many, especially the lower animals, are able to survive a period of freezing; others protect themselves by a coat of fur, feathers, or fat; and some, such as bears, lie dormant in a protected place during the cold season.

Most water and many land animals are cold-blooded; that is, their temperature changes with their surroundings. They require so little air that many of them obtain all they need from the water. Other animals, the birds and mammals, are warm-blooded, the warmth being due to slow combustion caused within their bodies by the oxygen they breathe (p. 229). Such animals require much oxygen and, even if they live in water, as the whales do, must rise to the air to obtain it. Those that live in water, or in cold climates, need to protect themselves by a warm covering in order to keep the warmth in their blood.

Animals differ from plants in the way in which they secure food. While some remain fixed in one place, depending on supplies brought to them, as plants do, most animals seek their food. They need carbon and mineral substances, but are unable to secure them directly from air and earth. They depend upon plants to perform this work, and the basis of animal food is, therefore, plant life. Even the food of flesh-eating animals may be

traced back to the plant kingdom. Thus plants are of vital importance to animals.

Unlike plants, animals do not absolutely require sunlight, since they do not need it to transform air, water, and mineral matter to food, as plants do. Consequently, animals are able to live even in the darkness of the deep sea.

Like plants, animals are strikingly adapted to their surroundings; if they were not, they would perish. Some spend most of their time in the air; some live part or all of the time in water; some dwell in trees; some have homes on the land surface; and some dwell at least part of the time underground. Flying, climbing, swimming, and running are developed to aid either in securing food or in escaping enemies. For these purposes there are many modifications in the shape of the body,—for example, wings for flying; long arms, claws, and tails for climbing; fins and boat-shaped bodies for swimming; long legs for running.

Gravity influences the form and structure of the body. Since man stands upright, two legs only are required; but four legs are necessary to sustain a body that extends parallel to the ground. Strong bones, or other structures, are needed to support the body on land; but in water, which is denser, bones, where present, are much lighter. To maintain themselves in the air, flying birds have more feathers and lighter bones than running birds, and in most cases their bodies are smaller.

Summary.—*All animals must have air for breathing, water for blood and tissues, and a temperature neither too high nor too low. There are both warm and cold blooded animals, and all are dependent on the plant kingdom for food. Animals are, in many ways, adapted to their surroundings; and there are many modifications fitting them to secure food and escape enemies. Gravity influences the form and structure of the body in many ways.*

228. Animal Life, or Fauna,[1] of the Arctic.—No animals

[1] A fauna is the assemblage of animals occupying a region. Thus we may speak of a Greenland fauna, an Alaskan fauna, etc.

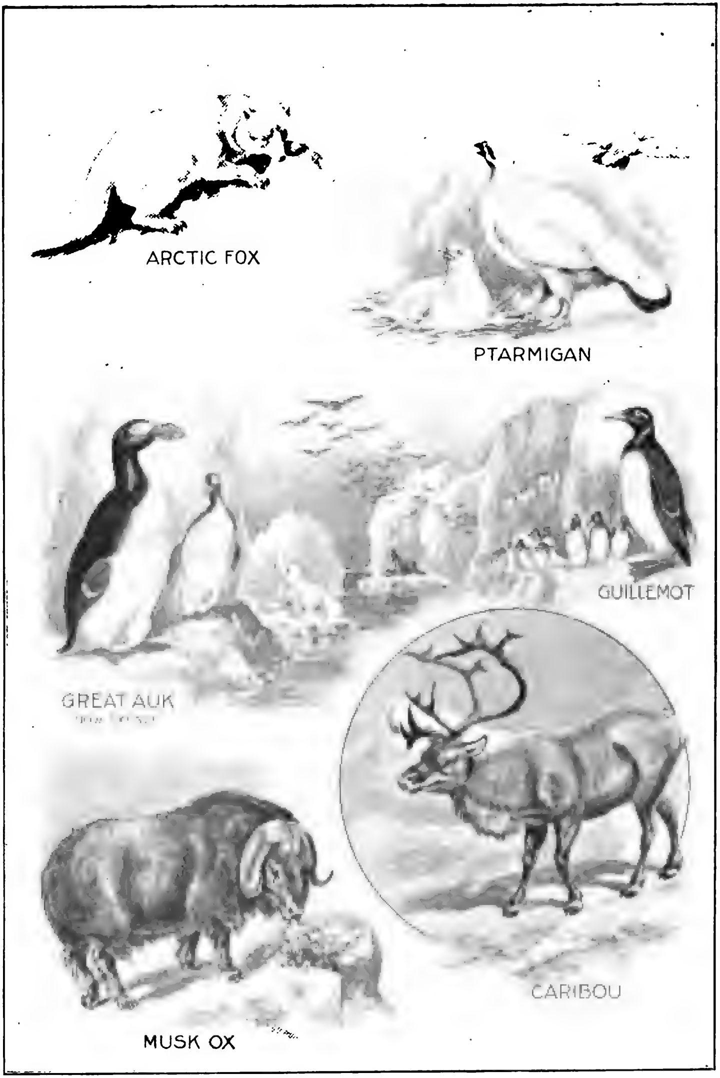

FIG. 505. — A group of Arctic animals.

FIG. 506. — Polar bear and Arctic seal. The legs of the seal are changed to finlike appendages, used for swimming and for climbing upon the ice.

FIG. 507. — Walrus. The legs have been modified for swimming and for climbing upon the ice.

FIG. 508. — Arctic whale. The legs have almost disappeared, and the tail is used for swimming. In the mouth of this whale is a large amount of valuable whalebone, on the edges of which are fringes which strain from the water the small animalculæ upon which the whale lives.

live in the ice-covered interior of Greenland; but in and near the Arctic Ocean there is much life, especially in summer. There are many kinds of fishes and other sea animals, and a great variety of sea birds feeding on them. When the freezing of the sea and land cuts off their food supply, most of the birds are forced to go southward; wild geese, for instance, which spend the summer on the tundras of northern America, fly as far south as Mexico. Other species go no farther south than Labrador and Newfoundland. During the summer, birds congregate in great numbers in their breeding places and, when frightened from their nests on the cliffs, rise into the air in clouds.

On the land there are crows, ptarmigans, and some smaller birds; also hares, foxes, reindeer (called caribou in America), and musk ox (Fig. 505). There are practically no reptiles, for the great cold is unfavorable to such cold-blooded animals; but there are numerous insects, of which the mosquito is especially abundant.

A number of mammals live part or all of the time in the sea. The polar bear spends most of his time on the sea ice, seeking the seal for food (Fig. 506). There are walruses (Fig. 507) and a number of species of seal, — warm-blooded, air-breathing mammals, which now and then leave the sea for a short time and take to the ice or shore. Whales also live in the Arctic (Fig. 508), but, though air-breathing, they never leave the water.

The warm-blooded animals are well adapted to life in the severe Arctic climate. They are well protected, the birds with warm feathers and down, which keep out wind, water, and cold, the mammals with fur or fat, or both. In winter, when most needed, the fur is thickest. Eider down and the fur of the fur seal of Bering Sea are highly valued for their warmth and beauty.

Many Arctic animals, like the fox, hare, and polar bear, are white like the snow and ice around them, thus escaping notice, both from their foes and their prey. The ptarmigan becomes white

in winter; but its summer plumage resembles the vegetation amid which it feeds. The baby seal, which spends its first days on the ice, is also white; but as it grows older, and takes to the water, its color changes to more nearly resemble the water.

Summary. — *In the Arctic region there are many sea birds, which move southward in winter when the freezing of sea and land cuts off their food supply. On the land there are a few birds and mammals, numerous insects, but practically no reptiles. A number of mammals live part or all of the time in the sea. Warm-blooded Arctic animals are protected from the cold by fur, feathers, and fat, and are often white like the surrounding snow and ice.*

229. Temperate Fauna. — In the temperate zones animal life is more varied, and differs greatly from place to place. Certain species, like the bison (Fig. 518) and antelope, have become especially adapted to life on open plains; others, like the moose and squirrel, to the forest; others, like the mountain sheep and chamois, to high mountains; others, like the jack rabbit, coyote, and camel, to arid lands. Some, like the blindfish, live in caves, losing their eyes because they are not needed in the darkness. Still others, like the earthworm, woodchuck, prairie dog, and mole, burrow in the soil, spending part or all of their lives underground. Some, like the owl and wild cat, sleep by day and hunt by night when their prey are asleep; but the majority rest when it is dark.

An enumeration of all the animals of the temperate zones would be a long list, for there is much variety among mammals, birds, reptiles, insects, and other groups. Among the birds are hawks, eagles, owls, humming birds, thrushes, and a large number of singing birds; and along the coast there are many sea birds, including gulls, terns, ducks, and snipe. Among mammals are the bear, fox, wolf, deer, antelope, elk, moose, wild cat, squirrel, and hare, besides others mentioned above (Figs. 509, 510). One peculiar animal of the United States is the opossum, which belongs to the same division of the animal kingdom as the kangaroo.

Many animals of the temperate zone are protected by a coat of

Fig. 509. — A group of cold temperate American animals.

Fig. 510. — A group of animals of western United States, found in the mountains or on the arid plains and plateaus.

fur, highly prized by man. Fur-bearing animals of value, including mink, otter, sable, and beaver, are found especially in the cold north, where they are still hunted. The beaver (Fig. 509), a very interesting animal, cuts down trees and bushes with which to build dams to make ponds and swamps in which its plant food grows. His sharp teeth and flat tail are especially adapted to this work.

Summary. — *Animal life in the temperate zone is abundant and varied, different species being adapted to life on the prairies, in the forest, on mountains, in arid lands, in caves, and underground. Many mammals have fur of value to man.*

230. Tropical Fauna. — Since plants are the basis for animal food, animal life thrives where plants abound. Hence, animals are abundant in the tropical forest. Innumerable insects, feeding on pollen, honey, leaves, bark, wood, or decaying vegetation, some in trees and some on the ground, furnish food for countless birds. The insects include many beautiful butterflies; also the interesting white ants, or termites, which build great structures of earth in which to dwell.

The birds, including parrots, paroquets, humming birds, and birds of paradise, number thousands of species. There are also many reptiles, including turtles, alligators, lizards, and snakes. Among the snakes are poisonous species, and huge boa constrictors, which, hanging from the trees, resemble thick vines. One of the lizards, the iguana, attains a length of several feet. The mammals include the lion, tiger, hippopotamus, rhinoceros, giraffe, and elephant of the Old World (Figs. 511, 512), and the jaguar, puma, tapir, armadillo, and sloth of the New (Fig. 514). There are also monkeys, orang-outangs, gorillas, antelope, deer, zebras, and many other mammals.

Summary. — *The abundance of plants in the tropical zone permits the existence of a great variety of insects, birds, reptiles, and mammals.*

231. Desert Fauna. — A complete list of the desert animals would be much shorter than that of a humid forest

region. There is a great contrast between the abundance and variety of life in the African forest and its paucity in the Sahara desert. There is also a decided contrast between the abundant and varied life in an Arkansas forest and the limited fauna of the desert portion of southwestern United States. There the chief animals are the antelope, puma, coyote, jack rabbit, cotton-tail rabbit, rattlesnake (Fig. 510), horned toad, and a limited number of birds and insects.

Animals need to be peculiarly adapted for life on a desert; and their number and variety are limited by the small amount of water and plant food. Some, like the snakes, require little water, aside from what they secure from the animals they eat; others are supplied with water from the roots or stems of the desert plants upon which they feed; and still others live near springs, or go long distances to them. The camel (Fig. 512) is wonderfully adapted to desert life. It is able to make long journeys on the desert because of the store of water which it carries in its water pouch; its broad, flat feet are admirably suited for travel over sandy surfaces; and its nostrils may be closed to keep out sand which the wind blows about.

Summary. — *The dryness of the climate, and the scarcity of plant food, limit animal life in the desert; but some species, like the camel, are peculiarly adapted to such a life.*

232. Fresh-water Fauna. — Rivers and lakes have varied faunas, including especially fishes, insects, and lower invertebrates, or animals without a backbone. Among fishes many are of value for food, and some, such as salmon and shad, come from the sea into fresh water to lay their eggs. A number of birds and mammals, such as the duck, beaver, muskrat, mink, hippopotamus, and manatee or sea cow (Fig. 514), spend part or all of their time in fresh water, feeding on water plants and animals. Many insects and amphibia (toads, frogs, salamanders, etc.) breed in water, coming to dry land during a later stage. Numerous reptiles, including crocodiles, alligators, turtles, and some snakes, live in fresh water.

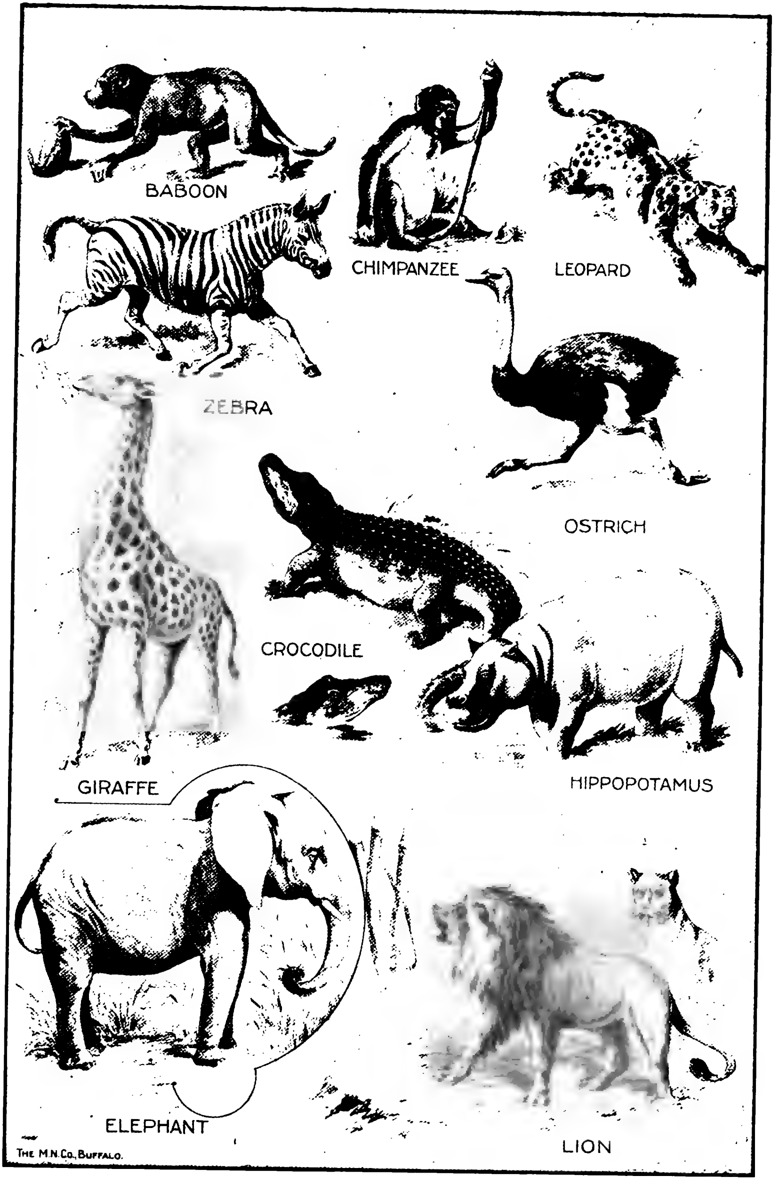

FIG. 511.— A group of African tropical animals.

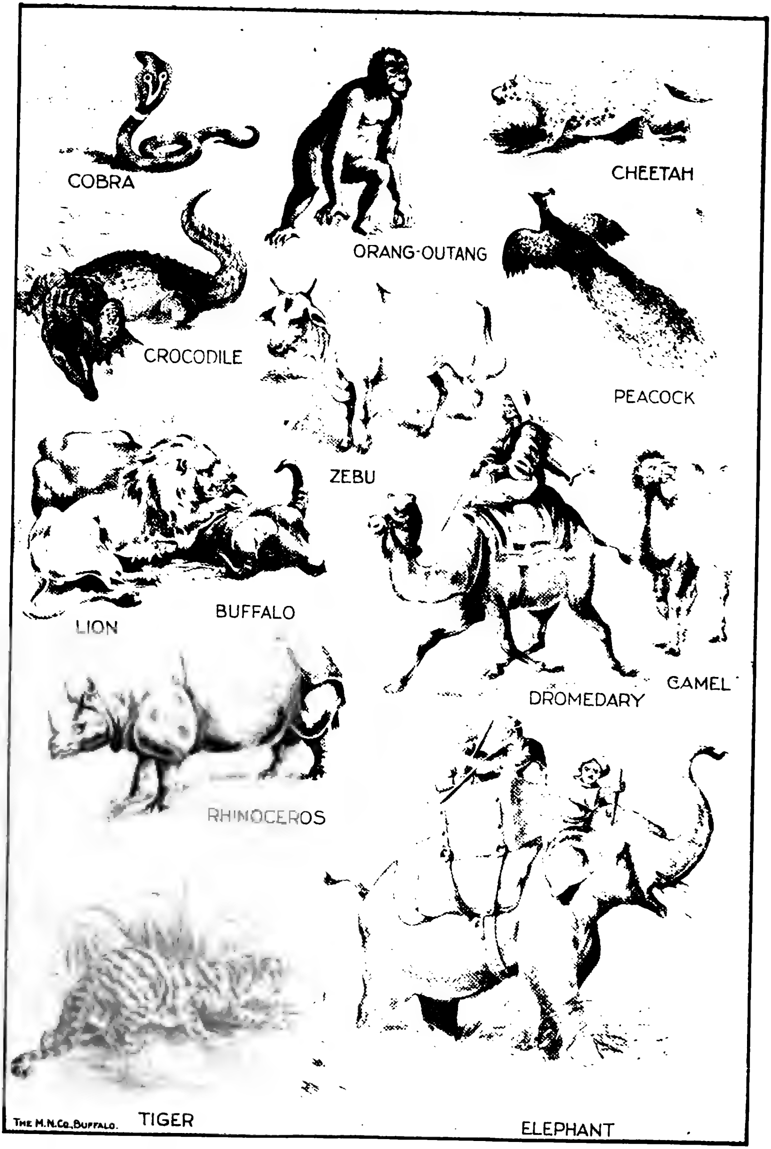

FIG. 512. — A group of southern Asiatic animals.

There are many differences in fresh-water life. For example, the faunas of muddy water, sandy bottoms, swampy ponds, quiet water, and flowing rivers are quite different. Cold water supports less abundant and varied faunas than warm; and salt lakes have very few animals. The Dead Sea receives its name because of the general absence of life, contrasting strikingly with the fauna of the neighboring fresh-water Sea of Galilee.

When arms of the sea are inclosed and changed to fresh water, most of the marine animals die, though some species may survive; also marine animals that enter fresh water may be prevented from returning to the sea. The landlocked salmon is a sea fish that has adapted itself to permanent life in fresh water.

Summary. — *Lower invertebrates, insects, fish, birds, mammals, amphibia, and reptiles are adapted to life in fresh water; and faunas vary with surrounding conditions.*

233. Homes of Animals. — As a whole, invertebrate animals are peculiarly suited to life in water. Insects are the principal exception, though spiders, snails, and other invertebrates are also land dwellers. While most insects live on land, many live in fresh water, and a few in the sea; and some, such as the mosquito, spend the early part of their life in the water.

Reptiles and amphibia are inhabitants of land and fresh water, though some, like the turtle, live in the sea.

While some birds, such as the penguin, ostrich, emu, and rhea, are unable to fly, most birds are especially fitted to live partly in the air and partly in trees or on the ground. Many, like the duck and penguin, spend much of their time in the water.

Mammals are mainly land dwellers; but the limbs of the bat have been changed for use in flight, and of the seal, walrus, sea cow, and others for use in swimming. Not a few, like the monkey, sloth, opossum, wild cat, and jaguar, spend most of their lives in trees.

Summary.—*Invertebrates are typically water dwellers, though some groups, especially most of the insects, live on the land. Reptiles and amphibia are land and water dwellers; birds, typical air dwellers, are also found in the water and on the ground; mammals, typical land dwellers, are also found in the air and water.*

234. Spread of Animals. — As in the case of plants, there is a tendency for animals to spread. To insure this, more young are born than can possibly live, some dying for lack of food, others being killed by enemies. It is during the young stage that animals are least able to protect themselves, and those animals, like fishes, which do not protect their young, must lay thousands of eggs in order that one of their offspring may reach maturity.

It is a great step in advance when the young are protected and fed by the parents, as among birds and mammals, or among bees and some other insects. Then, since they receive protection during the critical stage of youth, fewer offspring are necessary. Those animals that take the best care of their offspring are the highest.

The tendency to spread has taken animals to all parts of the earth; and evolution, or the tendency to change so as to become better adapted to surroundings, has caused them to vary. It is because of evolution that the European reindeer and American caribou, though of the same stock, are slightly different. The African elephant is a different species from that of Asia, though from the same original source; and the mammoth and mastodon, living in a cold climate, had a hairy coat, quite unlike the elephants of warm regions.

Ocean dwellers (p. 195) are among the most widespread of animals. They swim, or are drifted, here and there; and their surroundings are so uniform that there is little reason for change. Because they can fly, insects, birds, and bats are among the most widely distributed of land animals. Those animals that walk or crawl move more slowly, meet more enemies, and find more barriers to overcome, such as rivers, mountains, deserts, and sea. For these reasons the large mammals and running birds are usually confined to limited areas. Yet some, especially the fierce carnivorous animals, cover a wide range; the tiger, for example, lives in the hot jungle, on open plains, and on cool mountain slopes.

Summary. — *Many animals make provision for the spread of the species by the production of numerous offspring ; but higher animals protect their young so that fewer offspring are necessary. Animals have migrated to all parts of the earth, fitting themselves by evolution to their surroundings. Ocean and flying animals are most widely distributed, while land dwellers move more slowly and are often confined to very limited areas.*

235. Barriers to the Spread of Animals. — The spread of animals is interfered with by the same barriers as in the case of plants. Water is the greatest barrier; but it is overcome by flying animals and by those small forms that may be drifted, clinging to logs. The tropical forest is a barrier to a desert animal, and the desert to one that needs water every day. Nor can animals accustomed to a warm climate, or to life on plains, easily cross to the other side of a cold, rugged mountain range. Thus very different faunas may exist on opposite sides of such barriers, though some species, especially those that fly, will be the same on both sides.

Summary. — *The same barriers — water, desert, and mountain — affect both animals and plants; they are most easily overcome by flying animals.*

236. Island Faunas. — The influence of the ocean as a barrier is well illustrated by the Bermuda Islands, which lie about 600 miles east of the Carolina coast, the nearest land. They have never been connected with the continent, and yet the animals and plants are quite like those of the mainland. The flora includes the cedar and other northern plants, and cactus, palmetto, oleander, and other southern forms.

The fauna consists principally of insects and birds, including ground doves, redbirds, bluebirds, and catbirds, like those on the mainland. A small West Indian lizard is also found ; and there are bats, the only native mammals.

The lizards, and some of the insects, were probably drifted there by ocean currents; the birds, bats, and many insects,

flew across or were drifted by the wind. Every year birds from the mainland are seen in Bermuda, some resting during migration, others driven out to sea by winds.

It is not at all uncommon, far from land, to see small birds resting on the spars and decks of vessels; and even the tiny humming bird has found its way as far as Bermuda. Doubtless the small land birds, driven out to sea during storms, find resting places on logs and clusters of floating seaweed; but many must perish.

Similar conditions exist in the Azores, off the European coast, and the Galapagos Islands, west of South America. The word *Azores* means hawk, and *Galapagos*, turtle, the names being given because these animals were common when the islands were discovered. Animals have crossed the ocean barrier to even the most remote islands, like the Hawaiian Islands in the mid-Pacific.

Summary. — *The Bermuda and other islands, even the most remote, have plant and animal life from the mainland, showing that the ocean barrier can be crossed. Every year, birds stop on the Bermudas during migration, or because drifted out to sea by storms.*

237. Australian Fauna. — The fauna and flora of Australia are both peculiar. Among the birds are the emu and cassowary, two running birds; also parrots, lyre birds, and other peculiar kinds. The mammals include several species of *marsupials*, the very peculiar *monotremes*, and a few other species (Fig. 513). The monotremes, the lowest order of mammals, are represented by the remarkable duck-billed platypus (Fig. 513), which, unlike other mammals, lays eggs. The marsupials, another low order of mammals, to which the opossum belongs, include the kangaroo. These animals carry their young in a pouch, and, instead of walking, hop about by means of their long hind legs and stout tail. Although higher forms of mammals inhabit southern Asia and the East Indies, they have not found their way to Australia.

The explanation of this peculiar life is as follows. Fossils in the rocks prove that, far back in time, monotremes and marsupials

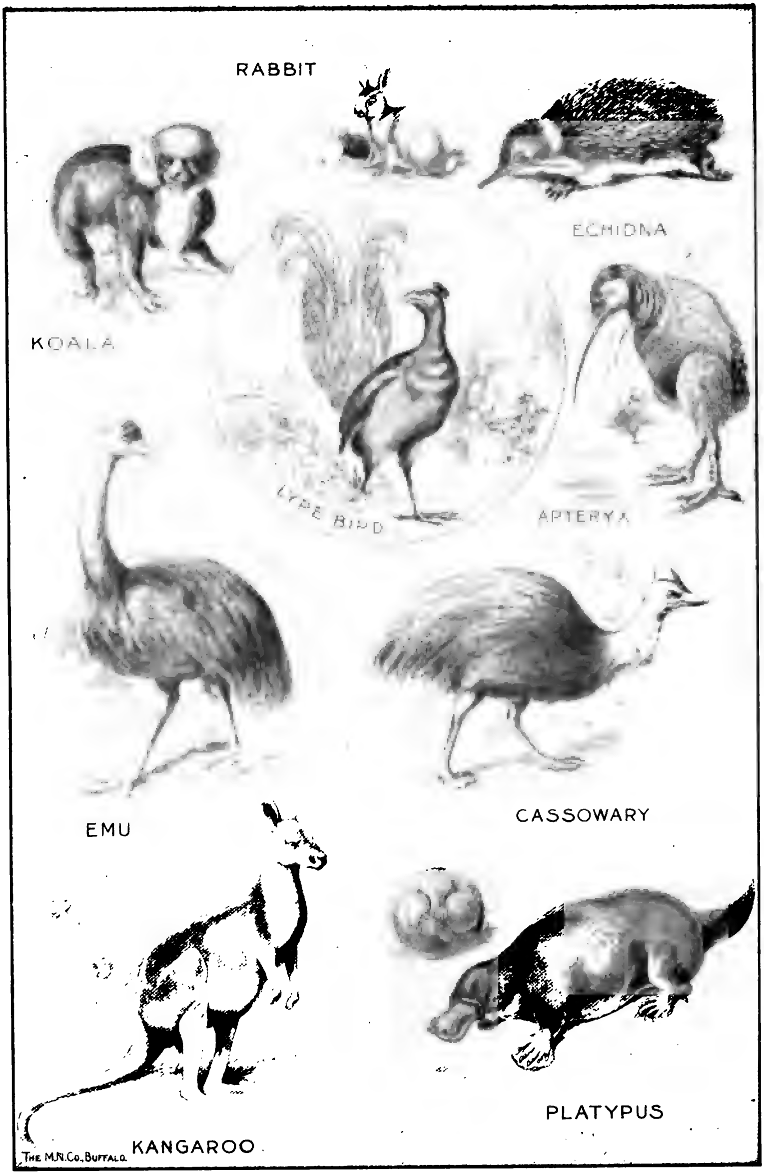

Fig. 513. — A group of Australian animals.

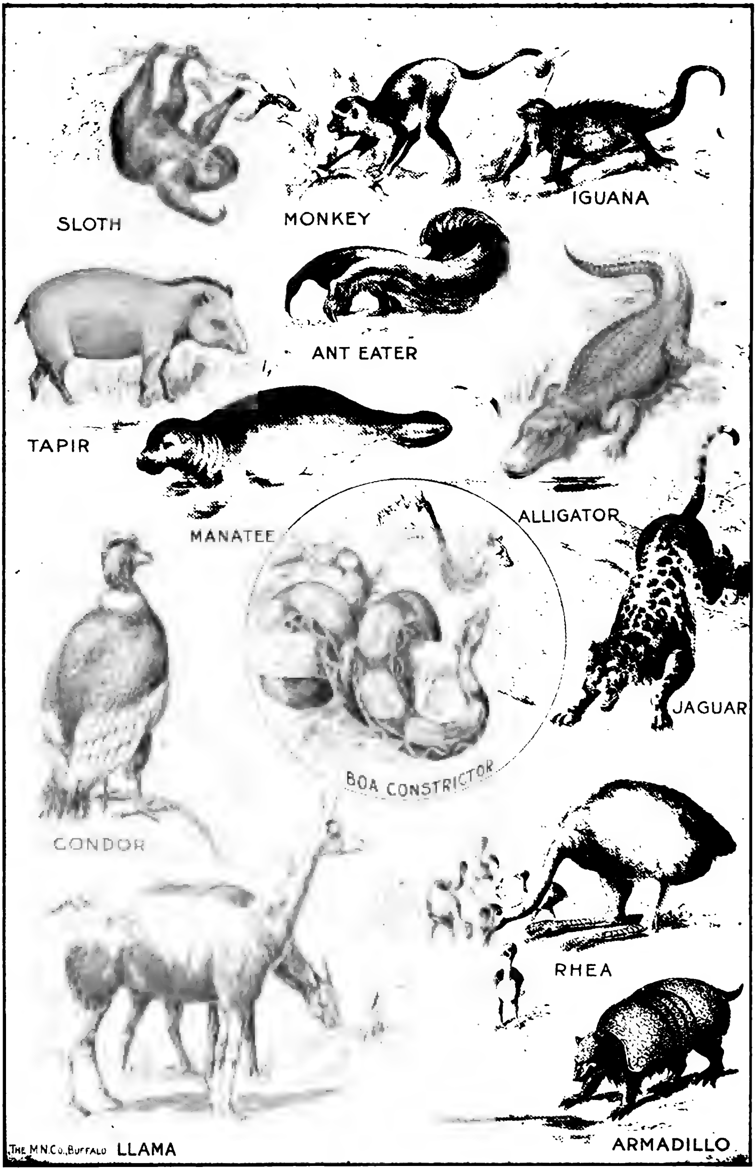

Fig. 514. — A group of South American animals.

were widespread. Australia was then so connected with other continents that these animals were able to migrate there. Fiercer animals have developed in the other continents and have killed off the monotremes and most of the marsupials; but they have been prevented from reaching Australia because sinking of the land has cut off its connection with other continents. Therefore, animals that belong to the geological yesterday are to-day living in Australia, though unfit to survive in other lands. They remain there only because the ocean protects them from the invasion of stronger species. Even dogs, introduced by man, and now running wild, are playing havoc among the defenseless marsupials.

Summary. — *The Australian fauna is peculiar, because the ocean barrier has prevented stronger species, developed on other continents, from entering and destroying the defenseless animals that came long ago, before these stronger species had been evolved, and when Australia was united with other lands.*

238. South American Fauna. — South American animals are also peculiar, though less so than those of Australia. The huge condor (Fig. 514), the largest of flying birds, lives there; also the rhea, a running bird, sometimes called the American ostrich; the llama and its allies; various species of monkey; the sloth; the ant-eater; the armadillo; the tapir; and other strange forms (Fig. 514). The fact that these peculiar animals exist in South America, while only part of them extend up into southern North America, leads to the belief that South America has also been cut off from other lands, though not for so long a time, nor so continuously, as Australia.

Summary. — *The peculiar fauna of South America also indicates a former separation from other lands, but not so long or so continuous as in the case of Australia.*

239. Faunas of Other Continents. — There is much closer resemblance between the life on other continents. In the north temperate zone there is such resemblance as to lead to the belief that there has been even better connection in the past than at present. For example, hairy elephants (mammoths and mastodons), now extinct, lived in Siberia, Europe, and North America; and among

living animals, there are close resemblances throughout the whole region. The faunas of Africa and southern Asia are also quite alike (Figs. 511, 512), indicating close connection.

Summary. — *There is close resemblance between the faunas of northern Asia, Europe, and America; also Africa and southern Asia, indicating former land connection.*

240. Zones of Animal Life. — The distribution of animals, described above, has led to the division of the earth into several zones, *realms and regions* (Fig. 515), each differing in important respects from the others. The differences between these zones are due to two principal facts: (1) that barriers — mountain, desert, and ocean — have checked the spread of animals; and (2) that evolution has developed animals of different kinds on opposite sides of a barrier. The boundaries of these zones are not sharply marked, nor are the zones absolutely unlike; for some species will find their way across even the greatest barrier.

Summary. — *Barriers and evolution have caused such differences among animals that several zones of animal life are recognized.*

241. Influence of Man. — Man has been a very important agent in causing changes among animals. In most parts of the world he has come in as an enemy, either seeking animals for his food or killing them because they destroy it. As a result, he has caused such a decrease among large wild animals that, in parts of America and Europe, very few remain.

Some species, like the bison, have been almost exterminated (Fig. 518). Others have completely disappeared, for example, the mammoth and mastodon, with whose final extinction savage man doubtless had something to do. The dodo, a large running bird in the island of Mauritius, and the great auk (Fig. 505), once so common along the northeastern coast of America, have also been exterminated. The eggs of the auk were eaten in large numbers, and the bird itself, which was unable to fly, was easily captured. A single specimen of the auk or its egg would now bring a very high price, for most large museums have none.

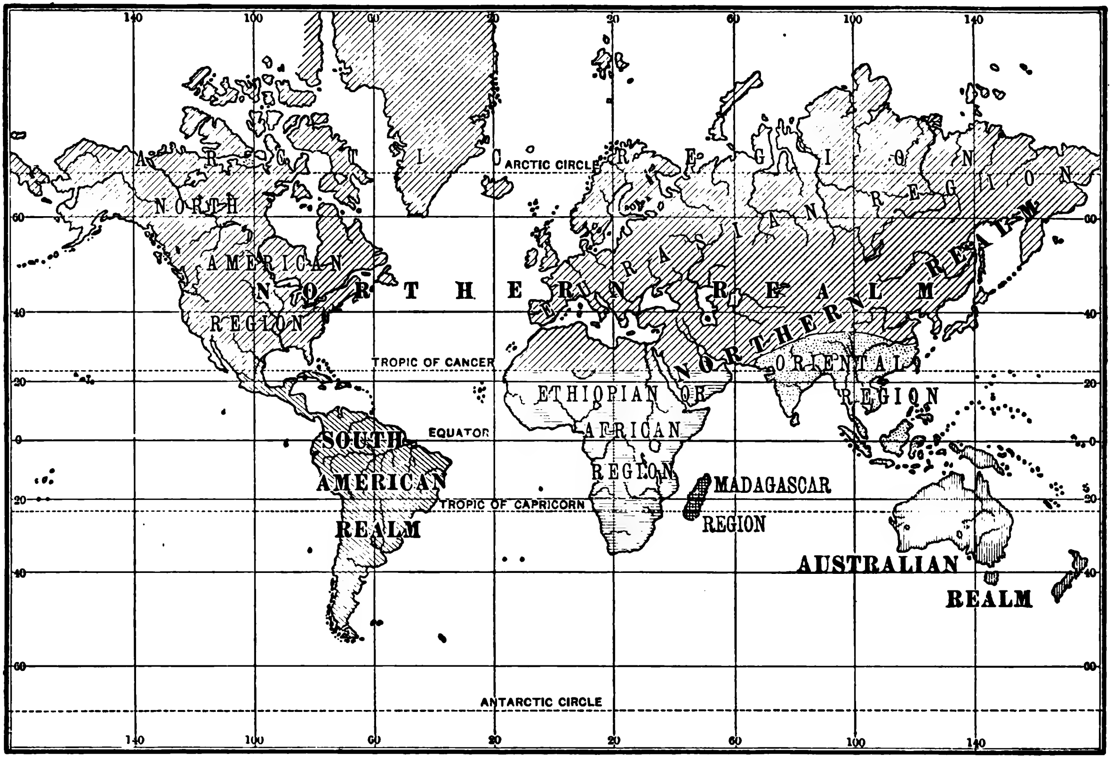

Fig. 515. — Map showing the three *realms* of animal life and the main subdivisions, or *regions*.

FIG. 516. — Sheep in the Scottish Highlands. A thick coat of wool fits these animals to endure the cold of a northern winter.

FIG. 517. — Shetland ponies, so protected by a heavy coat of hair that they thrive in the raw climate of the Shetland Islands.

On the other hand, some species thrive under the influence of man. For example, rats and mice have been carried all over the world and have so greatly increased as to become a pest; the English sparrow, introduced into America from Europe, has also become a nuisance; and so has the rabbit, introduced into Australia. The rabbit destroys the food needed for domesticated animals, and the Australian governments have been obliged to take up the question of checking its further spread. Such domesticated animals as sheep, horses, and cattle, have had their range so extended that they are now found in all quarters of the earth.

There is a limit to man's power in spreading animals. The camel and ostrich might be transplanted to southern California, but they cannot be made to thrive in New England; the elephant or tiger could not be introduced successfully into the Arctic; nor the polar bear into the tropics. Yet, with care, man has been able to transplant some animals into all kinds of climates.

Summary.—*Man has exterminated some species, especially the larger and more defenseless kinds, and has greatly reduced the numbers of many others. Under his influence, other animals have had their range greatly increased; but there is a limit to man's power of introducing animals into climates for which they are not naturally fitted.*

242. Domestic Animals.—Man has been very successful in adapting animals to his needs; and, by so doing, he has greatly increased his own prosperity. To have a horse or buffalo to help in his work, or sheep or hens for food, adds greatly to man's resources. He can do more work and make more progress; and the most advanced races are those with the greatest number and variety of domestic animals.

Some animals resist efforts at domestication; it seems scarcely possible, for example, to domesticate the lion. Yet it is remarkable how large a number of animals man uses. The reindeer of northern Europe (Fig. 546) is used as a draft animal and for food supply. Eskimo dogs (Fig. 525), which are little better than half-tamed wolves, are of great service in hunting and in drawing sledges over the ice. In the highlands of central Asia the yak is domesticated; the buffalo

(Fig. 520) and elephant (Figs. 512, 521) in southern Asia; and the camel (Fig. 519) in the arid belts of Africa and Asia. Cats, dogs, horses, cattle, sheep, goats, and pigs are domesticated all over the world. Among domesticated birds are hens, turkeys, ducks, geese, and doves.

As in the case of plants, the origin of many of these is not known; they date back thousands of years, long before the first records of history. It is a striking fact that the New World has supplied only two domesticated animals, the llama of South America (Fig. 514) and the turkey. If it had not been almost exterminated, the bison probably could have been domesticated. On several ranches in the West there are now small herds of bison from which it is yet possible that this animal may be domesticated.

Summary. — *While some animals resist domestication, man has succeeded in adapting many mammals and birds to his use, either for food or as work animals. Of these, the New World has supplied only two, the llama and turkey, though the bison may yet be added.*

Topical Outline and Review Questions.

Topical Outline. — 227. **Influence of Surroundings.** — Air; water; heat; cold; cold-blooded animals; warm-blooded animals; cause of warmth; protection; dependence on plants; sunlight; mode of life; means of securing food and escaping enemies; influence of gravity.

228. **Animal Life, or Fauna, of the Arctic.** — Animals in and near the sea; sea birds; southward migration; land birds; mammals; reptiles; insects; mammals in the sea; protection from cold; white color.

229. **Temperate Fauna.** — (*a*) Mode of life: open plains; forest; mountains; arid regions; caverns; underground; nocturnal animals. (*b*) Common animals: variety; birds; mammals; opossum; fur-bearing animals; beaver.

230. **Tropical Fauna.** — Plants; insects; birds; reptiles; mammals.

231. **Desert Fauna.** — Contrast with humid regions; fauna of southwestern United States; limit of food; source of water; the camel.

232. **Fresh-water Faunas.** — Kinds; illustrations; difference in surroundings; temperature; salt lakes; marine animals in fresh water.

233. **Homes of Animals.** — Invertebrates; insects; reptiles and amphibia; birds; mammals.

234. **Spread of Animals.** — Reason for large number of young; unpro-

FIG. 518. — A herd of bison. These animals formerly roamed over the prairies and plains of the West in enormous herds.

FIG. 519. — A caravan on the desert of Persia.

FIG. 520. — Asiatic buffalo, used as a work animal in southern and western Asia, eastern Europe, and northeastern Africa.

FIG. 521. — The elephant, being used for drawing cocoanuts from a cocoanut grove in southern Asia.

tected young; protection of young; evolution; reindeer; elephants; distribution of ocean animals; of air dwellers; of land animals.

235. **Barriers to the Spread of Animals.** — Water; forest; desert; mountain; animals that easily pass barriers.

236. **Island Faunas.** — (*a*) Bermudas: position; plants; animals. (*b*) Means of reaching islands: currents; flight; wind; birds at sea. (*c*) Other islands: Azores; Galapagos; Hawaiian Islands.

237. **Australian Fauna.** — (*a*) The animals: birds; monotremes; marsupials. (*b*) Explanation: former distribution; development of fierce enemies; separation of Australia; protection by ocean barrier.

238. **South American Fauna.** — Peculiar animals; explanation.

239. **Faunas of Other Continents.** — Resemblance in northern lands; in Africa and southern Asia; explanation.

240. **Zones of Animal Life.** — The zones; names; cause; boundaries.

241. **Influence of Man.** — (*a*) Man as an enemy: cause for destruction; general result; bison; mammoth and mastodon; dodo; auk. (*b*) Influence in spreading animals: rats and mice; English sparrow; rabbit; domestic animals. (*c*) Limit to influence; examples.

242. **Domestic Animals.** — Importance; instances of domesticated mammals; birds; New World animals; bison.

Review Questions. — 227. What is the dependence of animals on air, water, and temperature? By what means is cold endured? What is the difference in the blood of animals? Why are animals dependent on plants for food? Why are they not dependent on sunlight? In what positions do animals live? How are they fitted to secure food and escape enemies? State the influence of gravity on the body.

228. What is the nature of Arctic bird life? What is the condition of life on land? What warm-blooded animals live in the sea? How are Arctic animals protected from the cold? What about their color?

229. Under what different conditions do temperate animals live? Name some of the common birds. Mammals. Fur-bearing mammals.

230. Why are animals so abundant in the tropical zone? What is the condition of insect life there? Birds? Reptiles? Mammals?

231. Contrast desert and tropical forest faunas. What animals are found in the desert of southwestern United States? Why are there so few? How do they secure water? How is the camel adapted to desert life?

232. What kinds of animals live in fresh water? How do the faunas differ? How may marine animals come to live in fresh water?

233. In what situations do invertebrates live? The higher groups?

234. In what way is the spread of animals made certain? Give illustrations of evolution. What kinds of animals are most widespread? Why? What about land animals?

235. What barriers are there to the spread of animals? What kinds of animals most easily overcome them?

236. What is the nature of the Bermuda plant and animal life? How has this life reached the islands? What is the condition in other islands?

237. What are the peculiarities of life in Australia? Explain this.

238. What does the South American fauna indicate?

239. What is indicated by the faunas of other continents?

240. What are the reasons for the zones of life? Name the realms. Name the regions of the northern realm (Fig. 515).

241. Why is man an enemy of many animals? Give illustrations of his influence in extermination. In increasing the range of animals. How is his power limited in this respect?

242. Of what advantage are domestic animals? Give instances of domestic animals in various parts of the world. What domestic animals has the New World supplied? What about the bison?

SUGGESTIONS. — No special suggestions are made for this chapter, largely because of the difficulty of offering suggestions adapted to large numbers of schools. Yet a teacher especially interested in this phase of the subject will find opportunity for illustrative work, — with books, pictures, specimens, and museums, if in a city; in the field, if in the country.

Reference Books. — WALLACE, *Island Life*, Macmillan Co., New York, 1892, $1.75; *Geographic Distribution of Animals*, Harper Bros., New York, 1876, $10.00; HEILPRIN, *Distribution of Animals*, Appleton & Co., New York, 1886, $2.00; BEDDARD, *Zoögeography*, Macmillan Co., New York, 1895, $1.50; LYDEKKER, *Geographical History of Mammals*, Macmillan Co., New York, 1896, $2.60; LE CONTE, *Evolution*, Appleton & Co., New York, 1891, $1.50; JORDAN, *Factors in Organic Evolution*, Ginn & Co., Boston, 1894, $1.25.

CHAPTER XIX.

MAN AND NATURE.

DEVELOPMENT OF MANKIND.

243. Early Man. — The origin of man is not known, although scientists generally agree that he has developed, by the process of evolution, from some high form of animal. This belief is based upon the close resemblance between the body of man and ape, and receives support from the fact that, in habits and mode of living, some savages are little above animals. But even the least civilized men have powers that no animal possesses, while civilized man is so far above the highest animals that some people believe it impossible that he is the descendant of an animal.

Whatever man's origin, it is certain that in his early stages he lived the life of a savage. When the Roman Empire was developing, the Germans and English were rude savages; and still earlier, the inhabitants of the Italian peninsula were in the same condition. To-day, both in the Old and New World, there are races that have not yet risen above savagery.

Summary. — *Man's ancestry is unknown; but it is generally believed that he has been evolved from some high form of animal. It is certain that early man was a savage.*

244. Dependence of Man on Nature. — Even the most civilized men are dependent on nature, as animals and plants are. Man must have air to breathe, water to drink, and food to eat. Furthermore, his sight depends on sunlight, and his speech and hearing on sound waves, transmitted through the

air. If his home is in a cool climate, he must have clothing and shelter; and he obtains materials for these from nature.

In these respects both savages and civilized men are dependent on nature; but to live as civilized men do, we must rely on other things as well. For warmth and light we depend on coal and oil; for manufacturing, upon coal and water power; for transportation, upon coal and wind; for communication, upon electricity; for many objects of daily use, upon mineral substances. The resources of the world are drawn upon by civilized man, and his powers have so developed that he has learned to adapt to his needs many of the products and forces of nature. Each year his ability to do this increases. In this respect man has risen immeasurably above all other forms of life.

Summary. — *All men depend on nature for air, water, and food; and civilized man is dependent for many other things. Each year he is learning better how to make use of nature.*

245. Food Supply. — Man began his conquest of nature because of the need of food. The steam engine, the factory, and wireless telegraphy are the climax of a series of inventions which began when, to the teeth and claws with which animals secure food, man added simple implements.

By using stone implements, such as spear and arrow points, hammers, and hatchets; by fashioning wood for handles and for bows; and by making simple hooks for fishing, early man greatly increased his ability to obtain animal food. Even to this day, savage races make use of such primitive implements (Fig. 522).

As an important source of food, primitive man made use of plants, especially the seeds, fruits, bulbs, and roots. The mandioca, sweet potato, potato, yam, plantain, banana, cocoanut, date, and the grains, including wheat, barley, rye, corn, rice, and millet, are among the leading plant foods. To gather these, scattered as they are in nature, required much work, and early man naturally found it profitable to plant

FIG. 522. — Philippine natives, showing how little clothing is necessary in such a hot climate.

FIG. 523. — Laplanders dressed in furs. Contrast with Fig. 522.

FIG. 524. — Eskimo women at Cape York, Greenland. Behind them is the summer tupic, or skin tent.

and care for them. Simple spades and hoes, at first made of stone or wood, aided greatly in this work.

By domesticating plants (p. 348) and animals (p. 365) a great addition was made to man's resources. Domestication is the basis of civilization, for it gave man the habit of working, of storing up for a season of need, and of trading; upon it also depends the idea of property and of the home.

To-day all the world depends for food on the farmer and herder. Wherever conditions favor, the land is cleared for farming, and the majority of mankind are engaged in the production of food for themselves or for those with a different occupation. The plow, the reaper, and the threshing machine have taken the place of the primitive spade and hoe. Thousands of railway cars and vessels are constantly engaged in moving products of the farms to places where men are engaged in other pursuits, or where the population is too dense to permit the production of all the food needed. Agriculture is by far the most important of industries.

Summary. — *The devising of simple implements for securing plant and animal food is the basis of modern invention. The domestication of plants and animals for food is the basis of our civilization. All the world depends for food on the farmer and herder, and agriculture has become the most important of industries.*

246. Clothing. — In a hot climate man has little need for clothing (Fig. 522); but in a cool or cold climate some protection is necessary. Without it man could not occupy the cold temperate zone. Various natural products, including skins (Fig. 523), wool, and plant fibers, have been used to protect the body. Early Germans and Britons were clothed in skins, as the Eskimos are to-day (Figs. 524, 525).

In cold climates one of the objects of hunting has always been to secure materials for clothing; and one of the objects of herding is the production of wool and leather, and of farming, the production of fibers for cloth. The principal vegetable fibers used for making cloth, rope, etc., are cotton, flax, hemp, and jute.

Wool, silk, furs, and leather are animal products, at present widely used by civilized people for clothing.

The production and manufacture of materials for clothing now rank among the great industries of the world. The fact that the most civilized races live in the cool temperate zones makes the production of materials for clothing far more important than if their homes were in the tropical zone.

Summary. — *Clothing is needed by all dwellers in cool climates, and for it, various animal and plant products are used. Since the most civilized races live in the cool temperate zones, the production and manufacture of clothing are among the most important of industries.*

247. Shelter. — Man has adopted many devices for securing shelter from the elements. The summer home of the Eskimo is a skin tupic (Fig. 524); his winter home a hut, or igloo, of snow or ice (Fig. 525). Indian wigwams were made of skins. The nomad of the deserts uses skins and blankets (Fig. 526), made of the wool of his domestic animals. Sod houses are still built in many regions. Grass huts, and branches woven into a simple shelter (Fig. 529), are common in the tropical zone; and some savages live there with almost no shelter. In parts of Europe and southwestern America, caves and overhanging ledges furnished shelter to primitive man.

Fig. 525. — Eskimo winter home, or igloo. Entrance is by way of a small ice tunnel, through which wind does not easily enter.

Long before the historical period, clay and wood were used, at first very crudely, as materials for building perma-

Fig. 526. — A tent of blankets used for shelter by nomads on the desert of Sahara.

Fig. 527. — Thatched house in the Philippine Islands, needed for protection from sun and rain, not cold. It is raised above the ground to avoid dampness and to prevent the entrance of animal pests, which are very troublesome.

Fig. 528. — Swiss house near the timber line in the Alps. The abundance of wood leads to the building of wooden houses; the strong winds make it necessary to weight down the roofs with large stones. Rough-hewn boards are used in these houses. In parts of Europe where wood is scarce, as in Italy, wooden houses are very rare.

nent homes. The use of wood began in forest regions (Fig. 528), at first doubtless by the use of boughs, branches, and logs; then of rough-hewn boards. Simple log cabins, some of which still remain, were built by pioneers in America.

Stone houses were probably first made by merely piling stones together, as is done to-day by the Cape York Eskimos. Then mud was used to fill the cracks, and later, mortar was employed. The first use of clay was in making sun-dried bricks, or adobe, still employed in arid countries, as the Holy Land, Spain, and New Mexico. These are too easily affected by dampness for use in moist climates; but the discovery of how to bake bricks by fire has made the use of clay possible there. In arid regions, where trees are scarce or absent, stone and sun-dried bricks are very widely used.

FIG. 529.—A negro village, the huts being made of woven branches, a very simple form of shelter.

Our fine wood, brick, and stone houses have been developed, by a series of improvements, from these simple beginnings.

The cold of winter calls for further protection than that furnished by clothing and houses. Fire supplies this, and it is safe to class the use of fire among the greatest of human discoveries. It has become of value not merely for heating, lighting, and cooking, but as the basis for much of our modern manufacturing. It has led to mining of coal, production of oil and gas, mining and manufacturing of iron, and many other industries. As a result

of its use, modern man has come to count as necessities hundreds of articles about which primitive man knew nothing.

Summary. — *Many primitive means have been employed for securing shelter; for example, skins, snow, blankets, grass, branches, and caves. The use of wood, stone, and clay doubtless started in a very primitive way: wood from the use of boughs and logs; stone from mere piles; and clay in the form of sun-dried brick. The discovery of fire has been of high importance, making possible manufacturing and thus opening to man's use many otherwise useless materials.*

248. Selection of Homes. — Doubtless early man had no fixed home, but wandered about in search of food, as many primitive peoples do to-day. When for any reason a home became desirable, two considerations led to the selection of a location: (1) nearness of food supply; (2) protection from enemies. Homes are still located by large numbers of people with the first idea in mind: for example, farmers, fishermen (Fig. 533), and hunters; but, fortunately, civilized men are no longer obliged to take account of the second.

FIG. 530. — Native houses in trees, New Guinea.

There are many illustrations of the location of houses on sites that give protection from enemies. Some savages build houses in trees (Fig. 530), and some on piles in water (Fig. 534), as the ancient lake dwellers of Switzerland did. The Pueblo Indians

Fig. 531.— An Indian pueblo in Arizona, on the top of a mesa, and overlooking the surrounding country. The steep face is difficult of access.

Fig. 532.— Ruin (on the right) of a castle on the Rhine, built in a position fairly safe from attack.

FIG. 533. — Houses built on a steep hillside in a mountainous peninsula south of Naples, Italy. A few spots on the slope are cultivated, but most of the land is unfit for cultivation. The houses are, however, near the water, and fishing is possible.

lived on top of steep-sided buttes and mesas (Fig. 531); others lived in caves and under overhanging ledges on cliff sides (p. 85). Castles in Europe were often built on hills, and other places difficult of access (Fig. 532); and, for further protection, strong walls were built around them.

Fig. 534. — New Guinea village, built, for protection, on piles in the water.

Summary. — *The homes of primitive man have been selected with reference to nearness of food and possibility of protection from enemies. For the sake of protection, homes have been located in trees, in the water, on cliff sides, and on hills.*

249. Location and Growth of Cities. — When scattered it is easier for men to secure sufficient food than when many live in a single place; but it is less easy to ward off the attacks of enemies. Largely for this reason, the custom has grown for men, even savages (Figs. 529, 530, 534), to gather into communities. From their villages, these primitive people go out to the neighboring fields, forests, and waters for farming, hunting, or fishing, and yet, being near together, are ready to resist attack. They are also ready for an expedition to attack a neighbor for revenge or profit.

The leader in attack or defense easily became chief of the village; and, if powerful enough, he might become ruler of several. Even at present nations grow in power and territory by conquering weaker peoples. Government has become very complex, and differs greatly among nations; but, like all our wonderful modern life, it had its beginnings in the simple practices of our early, uncivilized ancestors.

Many European towns grew up because of the need of defense. One man, more powerful than the rest, built a strong stone castle, perhaps on a hill, and protected the region about it by a wall. Farmers, soldiers, and others, under the protection of the castle owner, worked for him, lived in houses within the walls, and helped defend them when attacked. In Europe, hundreds of places like this are still to be seen, although no longer used for defense. Around some, with favorable situations, large cities have developed.

In locating cities, at present, there is no need of considering defense. The great cities of the civilized world are the capitals of large nations, and the busy manufacturing and commercial centers. London, Paris, Berlin, Vienna, Brussels, St. Petersburg, Madrid, Rome, Constantinople, and other large European cities are capitals. The first five are also manufacturing centers; and London, Paris, St. Petersburg, and Constantinople are able to carry on commerce by sea. Each of these cities has a location favorable to growth.

All flourishing cities in the world, whether great or small, owe their prosperity, in large part, to their favorable situation. Some, like Milan in Italy, and Vienna in Austria, are situated where routes of travel converge or cross. They had their beginning long before the days of railways; but the railway, making them centers of modern traffic, has greatly increased their prosperity. Many cities, like Cincinnati, St. Louis, Vienna, and Paris, are on rivers; and others, like Buffalo and Chicago, are on large lakes. Still others, like Genoa, Liverpool, San Francisco, and New York, are seaports. Such seaports as London, New York, Philadelphia, Baltimore, and New Orleans, which are at the mouths of rivers that open a pathway into the interior, have an exceptionally favorable situation.

Many cities, like Lowell, Lawrence, and Rochester, owe their growth to water power, which has encouraged manufacturing. Others, like Scranton, Wilkes Barre, Pittsburg, and Denver, owe

their development mainly to near-by mines. Can you mention other instances of cities whose growth depends on their favorable location? What has helped determine the growth of your own city?

Summary. — *The tendency of people to congregate in centers has its origin in the need of defense, and from it has arisen government. Some large European towns grew around fortified castles; but the largest have prospered either because they are capitals of great nations or are manufacturing and commercial centers. Flourishing modern cities are mainly located on one of the following sites: at the crossing of trade routes; on rivers, especially at their mouths; on harbors; on lake shores; near water power; near mines.*

250. Development of Commerce. — Even primitive men desire articles which they cannot produce. For example, remote Eskimo tribes will gladly exchange skins for pieces of wood; and central African negroes will trade ivory for simple trinkets. Two ways of obtaining desired objects are open: one to seize them, the other to give exchange for them; and both methods are resorted to. From exchange, commerce has developed.

Objects of trade were early carried overland, at first on foot, later by the aid of animals, even across deserts and mountains. The first commerce by sea was carried on in small, open boats, propelled by oars; later, sails were used. Even before Bible times, and before Europeans became civilized, caravans crossed the deserts of Asia Minor, bringing treasures from Asia. The inclosed Mediterranean offered opportunity for the extension of this commerce by sea and for the introduction of Asiatic civilization along its shores.

A powerful nation developed on the Grecian peninsula, and its irregular coast bred a race of sailors. Even to-day the Greeks are the sailors of the Mediterranean. The ancient Greeks carried their commerce to all parts of the Mediterranean, establishing colonies which later developed into powerful independent nations. As the boats were made larger, the commerce which developed among Mediterranean

nations was gradually extended into the open ocean, and even up the European coast to the British Isles. The Mediterranean may be called the cradle of early navigation.

When the Mohammedans interfered with trade between Europe and Asia, a sea route to India was sought. The Portuguese found one around Africa, and Columbus, in searching for one toward the west, discovered America. For the development of these new lands, and the valuable commerce with them, boats were made still larger and stronger. Then came the use of steam; and now huge steel ships carry the increasing commerce of the world over all oceans.

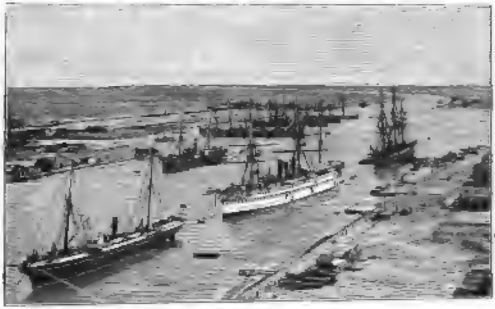

FIG. 535. — The Suez Canal. The neck of land which separates the Mediterranean and Red seas forced those who sought a water route to India, four or five centuries ago, to undertake the explorations which led to such important discoveries. The demands of modern commerce for a shorter water route between Europe and Asia led to the construction of the Suez Canal.

Commerce was once carried on by actual exchange of goods, and in some cases this is still done. But a far better way is to have some medium of exchange. Such a medium is money. The use of money is far simpler than direct exchange. For example, a man who needs shoes might find it difficult to get them if he had only his labor to offer; but if he receives money for his labor, he can get what he needs. Any substance that has a recognized and fairly uniform value could be used as money. Gold is generally used, because it is not too common, is not easily destroyed, and is valued by all peoples for ornament.

Commerce has aided greatly in the spread of civilization, for it has brought people into closer communication and sympathy with

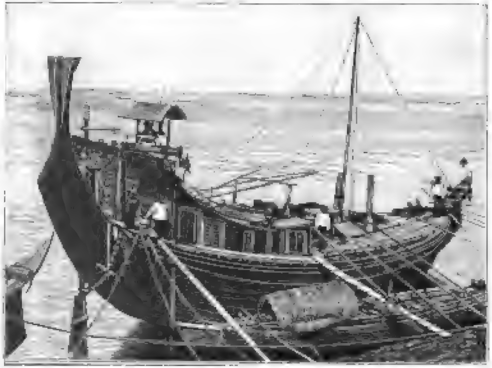

Fig. 537. — Burmese boat of very primitive type.

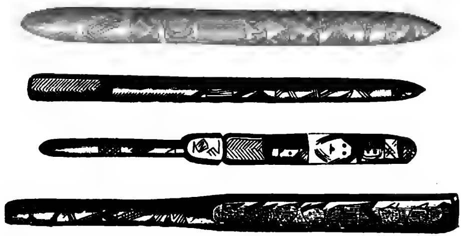

Fig. 538. — Message sticks used in West Australia to transmit messages.

Fig. 536. — A canal in Venice, a European city that was located on salt marshes, off the mainland, to secure protection from invaders. It developed into a very important commercial center, but has now given way to cities with better locations.

FIG. 539. — Bridge across the Firth of Forth, near Edinburgh, Scotland. This bridge, like many others, was built to accommodate the increasing modern commerce.

FIG. 540. — Shipping in New York harbor. Brooklyn Bridge behind the masts.

one another, and has made people in one section learn from those in another. As a means of communication, writing has developed, and, like other features of our civilization, this has been evolved from simple beginnings. For example, picture writing, or recording events by symbols carved on wood or stone, has been used by many primitive peoples (Fig. 538). From this the alphabet developed, then printing, which has been such an important aid in spreading knowledge. The telegraph, ocean cable, and telephone, made possible by the use of electricity, have now brought all parts of the civilized world in close touch with one another. Wireless telegraphy is the last great advance in communication. It is part of the progress of the human race toward higher and higher civilization, in which commerce has had so great an influence.

Summary. — *Commerce has developed from simple exchange carried on among primitive people, at first overland, either on foot or by the aid of animals, and on the sea by the use of boats propelled by oars. Early commerce between Asia and Europe, overland across Asia Minor, and thence in the inclosed waters of the Mediterranean, made the Mediterranean the cradle of navigation. The discovery of a water route to Asia, and of the New World, resulting from the closing of routes to Asia by the Mohammedans, have led to the development of larger ships and to the great advances of modern commerce. The use of money, the extension of civilization, the development of writing and printing, and communication by electricity are among the important outcomes of the development of commerce.*

251. Influence of Man on Nature. — In his progress, man has in many ways profoundly influenced his surroundings. He has modified, extended, and destroyed plants (pp. 348, 349) and animals (pp. 364, 365). By removing the forest he has made it possible for water to run off more rapidly (p. 50), washing soil into the streams and causing great variations in river volume. As a result, some streams formerly useful for water power are now too variable; and some areas, as parts of Italy, France, and Mississippi, have had their soil stripped off, leaving either bare rock or a surface too badly gullied for farming (p. 51).

On densely settled floodplains and deltas, the river courses have been controlled and annual floods prevented. Stream courses

have been straightened and deepened for navigation, and canals dug around rapids, and from ocean to ocean. For use in irrigation, river water has been led over arid lands; and lakes and ponds have been formed to secure steady water supply for irrigation and for other purposes. Each of these acts of man interferes with natural conditions.

Along the seacoast, walls are built to check the work of the waves. To better fit them for shipping, harbors and channels are dredged; jetties and sea walls are built to prevent currents from closing harbor mouths with sand bars; and, by building breakwaters, harbors are actually made by artificial means.

Much change is made on the dry land also. The ground is pierced with wells for water, oil (Fig. 542), and gas, and these substances are led to the surface. In the removal of coal, iron, and other mineral products, the strata are honeycombed with shafts and tunnels (Fig. 541); and in quarrying, and in removing clay and sand, hills are lowered and deep pits made. Tunnels are dug through mountains (Fig. 186) and deep cuts made in hillsides, while great embankments are built of the rock removed. Earth and rock are removed in making roads and in digging cellars; and, over great areas, the soil, by being loosened and overturned in plowing, is exposed to the weather.

These are some of the ways in which man is at work overcoming obstacles which nature has placed in the way of his advance. Civilized man brooks no obstacle; he removes it where necessary; he is everywhere at work modifying nature to serve his needs; and he is utilizing his surroundings, and the forces of nature, to help in his onward march toward higher civilization. In this respect man stands apart from all other forms of life.

Summary. — *In a multitude of ways man is influencing nature: destroying, modifying, or extending the range of animals and plants; removing the forest, thus allowing the rain to run off rapidly and carry away the soil; changing or controlling streams; improving or making waterways; forming lakes; interfering with the natural action of oceanic agencies; boring into the earth and removing materials; and exposing soil and rock to the weather. In fact, he is overcoming all obstacles and making nature serve his needs.*

Fig. 541. — A coal mine at Shenandoah City, Pa. Here the ground is honeycombed with shafts and tunnels, and vast quantities of coal are removed, together with associated rock, great piles of which are seen near the buildings.

Fig. 542. — Each of these derricks marks the site of a boring for oil at Tidioute, Pa., in 1870. From these wells large amounts of oil were obtained.

Fig. 543. — A part of the great Chinese wall, built to prevent invasion by hordes of Mongolians, spreading outward from central Asia.

DISTRIBUTION OF MANKIND.

252. The Spread of Man. — During the development of man, as outlined above, he has migrated to almost all lands. Starting from some common center, he spread slowly, guided by the same laws as animals, and influenced by the same barriers. But man's superior intelligence has permitted him to spread farther than any species of animal, and to adapt himself to all climates. Even as a savage he reached every continent and most oceanic islands. The use of boats aided him in crossing the ocean barrier; and, by means of clothing and shelter, he has overcome the barriers of cold climates.

The spread of man has been in part a slow, steady advance outward in all directions, as in the case of animals, and in part a rapid migration in large numbers It was such rapid spread that led to the building of the great Chinese wall (Fig. 543) as a barrier to the hordes that moved outward from central Asia. Similar hordes from Asia overran Europe; and still others crossed the Alps and advanced to Rome. The spread of man has often been a part of warfare and conquest. This is illustrated by the Roman Empire which, by conquest, caused the diffusion of Romans and Roman civilization, not only along the Mediterranean shores, but throughout western Europe, even as far as the British Isles.

The discovery of new lands, especially in the New World, has had a great influence on the spread of man. By the time of Columbus there had been such advance in knowledge of sailing, including the coming into use of the compass, that even the ocean could be crossed at will. The much higher civilization of Europeans enabled them to displace the savage occupants, not only of America, but of Australia and the more attractive parts of Africa. Commerce is at present aiding in the general spread of man.

Summary. — *The spread of primitive man was influenced by the same laws and barriers that affect animals; but man's superior*

intelligence, and especially the use of boats, clothing, and shelter, has made it possible for him to spread much farther. Man's spread has been in part slow migration, in part rapid movement in large numbers, often as a part of warfare and conquest. The discovery of new lands, occupied by savages whom he could displace, has greatly helped in man's spread; and commerce is now aiding it further.

253. Races of Mankind. — Although there are decided differences among men, all are believed to have come from the same stock. Through the influence of climate, and other surrounding conditions, they have become varied in color, form, and habits. On account of these differences it is customary to divide mankind into several classes, or races. There is (1) the black, or negro (*Ethiopian*) race; (2) the yellow (*Mongolian*) race; (3) the red, or Indian (*American*) race; and (4) the white (*Caucasian*) race. A fifth division, the brown (*Malay*) race (Fig. 545), is often recognized.

Because there has been a mixture of blood wherever they have come in contact, the boundaries between these races are not distinct (Fig. 544). Moreover, the members of one race have often migrated into the territory of another. Thus the Finns and Hungarians, though surrounded by Caucasians, are Mongolian in origin. The red men were originally confined to the American continent, and have never migrated to other regions. But other races have spread widely. In modern times the Mongolians have spread very little, and the negroes have spread mainly through the influence of white men, who have carried them as slaves, especially to the New World. The white race, on the other hand, has migrated extensively, taking the place of weaker and less well-fitted people. This is well illustrated in America, where the Indians have been slowly driven back by the aggressive, civilized Caucasians.

Summary. — *Mankind is divided into four main races:* (1) *the black, or Ethiopian;* (2) *the yellow, or Mongolian;* (3) *the red, or American; and* (4) *the white, or Caucasian. Because of intermixture and migration, the boundaries between these races are by no means distinct. The white race is now rapidly extending its range and influence, and is taking possession of the earth.*

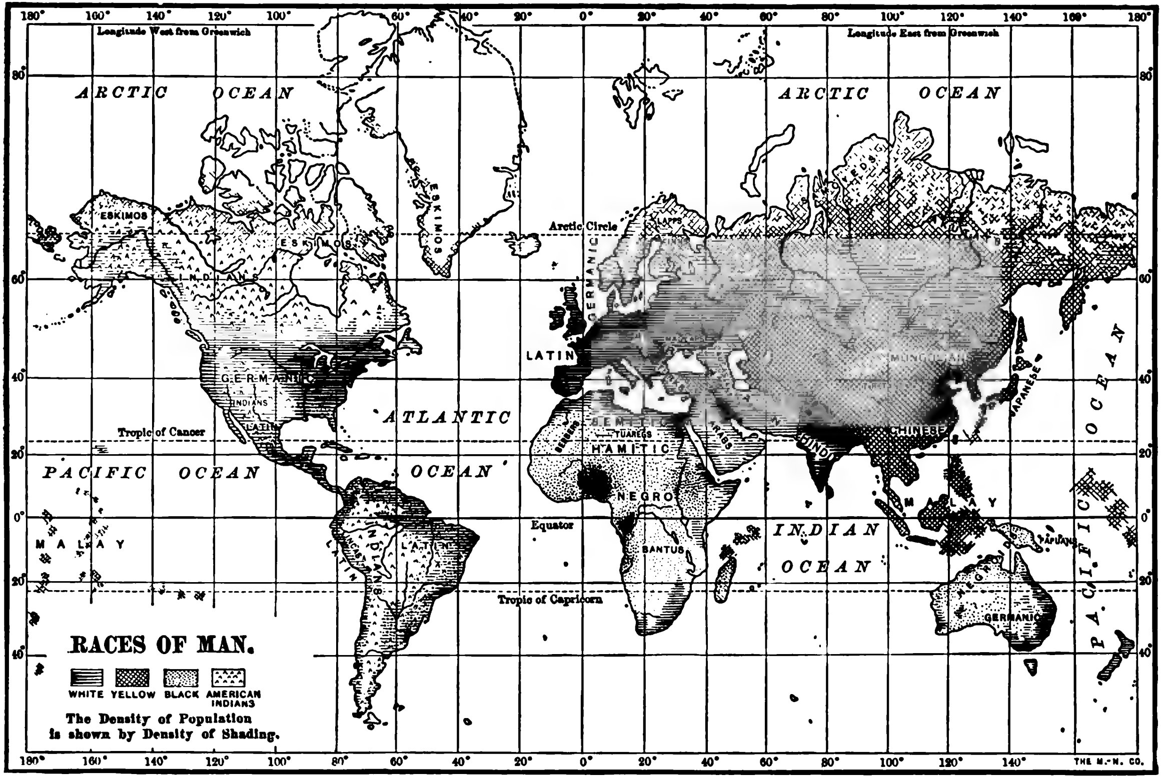

FIG. 544. — Sketch map, showing the general distribution of the four races of man.

FIG. 545.—Races of mankind. Red, or Indian, upper left; black, or Ethiopian, upper right; white, or Caucasian, middle; yellow, or Mongolian, lower right; brown, or Malay (a branch of the yellow race), lower left.

Characteristics of the Races of Mankind.[1]

	Ethiopian.	Mongolian.	American.	Caucasian.
Former home.	Africa, south of Sahara; Madagascar; Australasia (for example, Philippine Negritos).	Probably highlands of Tibet.	New World.	North Africa.
Present extension.	Africa; United States; West Indies; Nicaragua; Guiana; Brazil.	China; Indo-China; North Asia; Korea; Japan; Malaysia; Turkestan; Asia Minor; Russia (Baltic); Balkan Peninsula; Hungary.	Most are now found in Mexico, Central America, South America, and western United States.	All of Europe; India; northern, central, and western Asia; America; South Africa; Australasia; New Zealand; in fact, over almost all the world.
Physical characteristics.	Long, narrow head; projecting jaws; broad, flat nose; thick lips, rolled outward; large, round, black eyes; deep brown color, rarely black; short, black, woolly hair; scanty beard; height above average.	Broad, round head; moderately projecting jaws; small, concave nose; thin lips; small, oblique, black eyes; color yellowish, pale, and even white; long, coarse, black hair; no beard; height below the average.	Head both long and round; slightly projecting, massive jaws; aquiline nose; small, black eyes; color coppery, shading to yellowish or brown; hair long, coarse, black; scanty beard; height variable.	Two types: (1) fair; head long; moderately large, blue or gray eyes; long flaxen, brown, or red hair; height above the average; (2) dark; head long in south, round in north; large black eyes; hair wavy, curly, brown or black. In both types jaws small, nose large, straight, or aquiline.
Mental characteristics.	Unintellectual; unprogressive; no science or letters; few arts beyond agriculture and simple weaving, pottery making, etc.; religion very crude, including witchcraft, nature worship, and human sacrifice.	Sullen; sluggish; industrious in temperate zone, elsewhere indolent; arts and letters moderately developed, science slightly; their culture not of modern kind. In religion some are pagans, but most are Buddhists and Mohammedans.	Stern; moody; not emotional; vary from savagery to barbarism; slight knowledge of arts, for example, agriculture, pottery, etc. Highest had rude knowledge of letters and some simple science. Religion a superstition, with nature worship and human sacrifice.	Fair type solid and even stolid; dark type fiery and fickle. Both active and enterprising. Science, letters, and art highly developed. Religion varies from belief in one God to belief in several, and includes Christianity, Judaism, Mohammedanism, Brahmanism.
Numbers.	Africa 150,000 000 Madagascar 3,000,000 America 20,000,000 Australasia 2,000,000 Total 175,000,000	China, 380,000,000 Japan and Korea, 55,000,000 Indo-China, 35,000,000 Malaysia,[2] 80,000,000 Rest of Asia, 36,000,000 Miscellaneous, 4,000,000 Total, 540,000,000	Full blood 9,900,000 Half-breeds, 12,270,000 Total 22,170,000 Most in Mexico (8,765,000); Brazil, 4,200,000; 250,000 in United States.	Europe 355,000,000 Asia 280,000,000 America 115,000,000 Africa 15,000,000 Australasia 5,000,000 Total 770,000,000

[1] Based on table in Mill's *International Geography*.

[2] The brown race (Fig. 545), often recognized as a fifth division of the human race, is here included among the Mongolians.

INFLUENCE OF SURROUNDINGS.

254. Man in the Arctic. — Agriculture is impossible in the Arctic, and there is too little plant food to support human life (Fig. 486). Under such unfavorable conditions, the inhabitants of the North must look to animals for food; and, as these are most abundant in the sea, the shores of the Arctic are inhabited by a sparse population. On the tundras of Europe and Asia, the reindeer is domesticated, making it possible for more people to live than otherwise could. The caribou is not used by the Eskimos; but Siberian reindeer have recently been introduced into Alaska.

FIG. 546. — Natives near the timber line in northern Asia. Both the dog and reindeer are domesticated.

Life in the Arctic is well illustrated by the Eskimos (Figs. 524, 525), who live along the coast, depending for food chiefly on birds, seal, walrus, and bear. The extent to which these interesting people depend on animals is shown by the following: they obtain from them most of their food; skins for their clothing and summer tents, or tupics; bone for their spears; and bone framework and skins for their boats, or kayaks. Wood, occasionally drifted to their shores, is one of their most highly prized possessions.

To live amid such surroundings requires great hardihood and constant effort; and death by starvation is not uncommon. The Eskimo has to work hard in order to obtain the barest necessities, and there are no luxuries. How difficult his life must be is indicated by the disasters which have befallen many Arctic explorers. Such surroundings offer little opportunity for advance.

Summary. — *The Arctic is sparsely populated, mainly along the coast where there is most animal food; but in the Old World the reindeer is domesticated, increasing the chance of living. The Eskimo depends on animals for food and materials for shelter, clothing, and boats. Life in the Arctic is such a hard one that there is little chance for advance, all the energies being needed for obtaining the barest necessities.*

255. Man in the Tropical Zone. — Conditions in the tropical zone are quite opposite from those in the Arctic. There man is surrounded by an abundance of food, both plant and animal, and he requires little clothing (Fig. 522) or shelter (Figs. 527, 529, 530). All his needs are met with slight effort, and there is little cause for work. Moreover, the climate, especially if damp, is unfavorable to work. Under such conditions man resembles animals in being content with bare necessities. Being so easily satisfied, he cannot advance far in civilization.

It is for these reasons that some of the most uncivilized peoples of the world to-day are found in hot climates. The Indians of Central and South America, the negroes of central Africa, the Australian natives, and the Negritos of the Philippines are examples. Among many of these people, as among animals, the eating of one another, or cannibalism, is still practiced. They live in the most primitive way, — lazy, unintelligent, superstitious, human animals. Yet they talk, they think a little, and they know the use of simple implements. When brought under the influence of civilization they advance, showing that it is only surrounding conditions that have kept them so low.

Summary. — *In the tropical zone the ease of obtaining food, and the small amount of clothing and shelter necessary, call for little work, to which the hot, damp climate is unfavorable. It is for these reasons that the least civilized races are found in the tropical zone.*

256. Man in the Temperate Zone. — This zone has been the birthplace of civilization, mainly for the following reasons: (1) while there is an abundance of food in summer, there

is little in winter. It has, therefore, been necessary to secure food in summer and store it for winter use. This requires energy, intelligence, and foresight; yet the amount of work necessary is not great enough to discourage or to prevent advance. (2) Both clothing and shelter are needed, and to provide these also requires intelligence, ingenuity, and energy. (3) The lands of the temperate zone are irregular, and the climate varied. This has led to the growth of different crops in different sections; and the people of one section, desiring the products of another, have opened communication with them. From this has arisen commerce, leading people of one region to learn from those of another.

To meet the needs of winter, the people of the temperate zone have developed the habit of cultivating crops, and have devised means of making the work easy. They have domesticated animals for food and as aids in their work; they have made implements; have learned how to use metals; have developed the art of building; have discovered the use of fire; in fact, in supplying their needs they have learned to call all nature to their aid. The civilization that developed in the north temperate zone has now spread to all zones.

Summary. — *The need of providing food, clothing, and shelter for winter has caused people of the temperate zone to advance; and the varied products of different sections have given rise to commerce. In this advance the cultivation of crops, the domestication of animals, the art of building, and the use of metals and fire have been learned. Thus modern civilization has arisen.*

257. Man in the Desert.—Living on a desert resembles life in the Arctic in the fact that there is so little food that men often die of starvation. But the nomads of the desert (p. 89) have domestic animals, — cattle, horses, and camels especially, — which help them greatly. Their mode of life makes these wanderers intelligent and brave, otherwise they could not live amid such surroundings; but they do not hesitate to seize from others the goods they need.

Desert conditions are so unfavorable that people more civilized have not entered to crowd the nomads out; and the desert barrier prevents the inhabitants from learning of others. For this reason, customs of the time of Christ are to-day preserved among the inhabitants of the Old World deserts.

On oases conditions are very different, for there agriculture is possible. Large oases, such as the valleys of the Euphrates and Nile, have been cradles of ancient civilization. Civilization early developed in such situations because it was necessary to work in order to store up food for the season when crops will not grow; and the surrounding desert served to protect the stores of food from invaders.

Both in the Euphrates and Nile valleys, and in other oases of the Old World, there developed a wonderful ancient civilization, which spread along the shores of the Mediterranean. This ancient culture is the foundation of our modern civilization. The oases were favorable to the beginning, and the Mediterranean to the spread of civilization (p. 377); but the desert barrier has interfered with the introduction of the modern civilization which has developed in other parts of the temperate zone. Consequently, these cradles of ancient civilization are now far behind the world.

The most advanced of the American Indians were those that lived in similar situations. The Pueblo Indians of New Mexico, the Aztecs of Mexico, and the Incas of South America lived in positions where agriculture was possible, and where deserts or mountains offered partial protection from invasion. When discovered, these red men were barbarians, far higher than the other Indians, who were savages.

Summary.—*Because of lack of food and water, desert conditions are unfavorable, and the inhabitants are scattered and nomadic, though greatly aided by their domestic animals. The desert barrier prevents them from learning from others, and hence they preserve many ancient customs. The oases, however, were cradles of ancient civilization, because* (1) *agriculture was possible;* (2) *it was necessary to provide food for the unfavorable seasons;* and (3) *the desert protected the inhabitants from invasion.*

258. Influence of Mountains. — There is no part of the world where, in so short a distance, there are found races as different as those on the north and south sides of the Himalayas. These mountains have served as great walls (p. 106), hindering the migration of man as well as of animals; and it was partly because of their protection that the people of India became so civilized in very ancient times. Yet even these mountain barriers were crossed, although with great difficulty. Much the same is true of the Alps, whose protection helped to make the powerful Roman Empire possible.

When their country is invaded, people often retreat to mountains; for there is little about mountains to attract invaders, and entrance is difficult, while the passes and valleys are easily defended. For these reasons the Welsh and Scotch, who occupied the more mountainous parts of Great Britain, were far less affected by the inroads of invaders than the inhabitants of other sections of the island. To this day their ancient language is spoken, and sermons are even preached in it. In the Pyrenees there is a small group of people, called the Basques, who still retain an ancient language no longer spoken by others. In the single small country of Switzerland four languages are now spoken, — German, French, Italian, and Rætho-Romisch dialect.

Among mountain people ancient customs, as well as languages, are preserved. For example, homespun is still used in the mountains of eastern Kentucky; and peculiar, old-style costumes are worn by Swiss mountaineers and inhabitants of the Black Forest mountains of Germany. Such places, like deserts, are among the last to be reached by new customs.

Mountain people are brave and hardy, for their life is one of hardship, and there are many dangers. The open-air life, with plenty of space and freedom, develops a love of freedom. They desire to be left alone, and resist attempts at conquest. It is for such reasons that little Switzerland, notwithstanding many efforts to seize it, has been able to remain independent.

Summary. — *Mountains are barriers, protecting people from invasion; they are places of retreat before invaders; in them ancient languages and customs linger; they develop a brave, hardy, freedom-loving race.*

259. Influence of Coast Line. — Closed seas and irregular coasts, having quiet water, encourage fishing and commerce. It is along such coasts, therefore, that navigation has developed. The Mediterranean and the irregular Grecian coast illustrate this; also the irregular Scandinavian coast, with its many narrow, quiet fiords (p. 209). Here developed the brave, hardy Norsemen, who ravaged the coast of western Europe, and even visited America, before the time of Columbus.

The British nation has become "mistress of the seas" because of the favorable position and coast. No part of the British Isles is far from the sea; there are innumerable bays and harbors; and many of the inhabitants have engaged in fishing. The separation from the mainland has been of the highest importance, for it has prevented invasion by land and has made commerce by water necessary. Furthermore, these small islands are unable to supply food enough for the large manufacturing population that has developed there. To bring food, and to carry away manufactured products, calls for ships; and to protect these and the coast from attack, demands a navy.

Colonies were established as a source of food and raw products for manufacture; they also served as a market for manufactured articles, and commerce with them became great and mutually beneficial. As a result of these facts, and the presence of coal and iron for manufacturing, the British nation has become the greatest sea power in the world, and has come into possession of the largest amount of territory that any nation has ever controlled.

Summary. — *Protected seas, like the Mediterranean, and irregular coasts, like those of Greece and Scandinavia, encourage the develop-*

ment of navigation. The British nation has become the greatest sea power, and the possessor of the largest amount of territory, of any nation, as a result of its island condition, its irregular coast, and the fact that it needed to import food and raw products for manufacture, and, being on an island, was obliged to bring them by water.

260. United States. — The situation of United States in the temperate zone, with several different climates, is favorable to advance. There are great natural resources of nearly every kind, and the wisdom and love of freedom of our ancestors led them to establish a government that has encouraged the full use of these resources. The coast line is favorable to navigation, and the Atlantic Ocean, which separates us from other highly civilized nations, is so narrow that communication and commerce with them are easily possible. Yet it is wide enough to protect us from attack and invasion.

No settlers except Indians who roamed about.
Scattered settlements, such as forts, pioneer houses and small villages.
Fairly well settled.
Most densely settled portion. More than 90 people living on every square mile.

FIG. 547. — Distribution of white men in United States, 1790.

Early settlements were naturally first made along the coast, because this was the first place reached. Although the natives were finally pushed aside, for a while aided by the mountain and forest barrier, they held back the westward advance of the pioneers. Thus the settlers continued to live along the coast; and in 1790, when the West was a vast wilderness crossed only by Indian trails, it was possible to travel by stage from Portland, Me., to Virginia, stopping each night in a good-sized village.

The Spanish and French settlements were far more scattered, for the Spanish had two coasts to travel along, and the French had the great interior waterways. Therefore, when the French and Indian war came, the English, being closer together and able to unite, had a great advantage. The success of the Revolution was also in large part due to the fact that the Colonists were centered along the coast.

The mountains were finally crossed along the water gaps, through Cumberland Gap to Tennessee and Kentucky, and along the Mohawk Gap to the Great Lakes. When the way to the interior was well opened, migration was rapid, because the soil was good, the climate favorable, the surface clear of forest, and the land free to all. Soon the central plains developed into a great agricultural, mining, and maufacturing section. The water gaps and waterways are still the leading routes to this interior.

West of the prairies was another great barrier, in the form of arid plains and plateaus, extensive deserts, and lofty mountain ranges. How great a barrier this was is seen from the fact that, when gold was discovered in California, large numbers preferred to travel entirely around South America rather than undergo the danger and hardship of a wagon trip across the continent. Now several lines of railway cross the mountains; there are mining cities in the mountain valleys; and irrigated farms dot even the desert. Man has so overcome these barriers that the continent is crossed in a few days with all the comforts of modern railway travel.

Our country has developed wonderfully, and in a century has changed from a weak nation, struggling for existence, to one of the great world powers. This growth is not the result of a mere accident; nor is it due to a single cause. The invigorating climate encourages work, and in fact requires it; and intelligent labor secures great reward. In a new country there are wide opportunities for those who work hard, and this fact has helped make the American people

energetic. Mineral, farm, and forest products may be obtained in great variety; and physiographic conditions, as well as the wise government under which we live, are favorable to their development. It is no wonder that the United States has advanced so rapidly; and the present century should see still more wonderful advance.

Summary. — *The climate, resources, government, and coast line of the United States are favorable to advance. The early settlements along the coast, and the interference with westward spread, caused by the Indians and mountain barrier, helped make the English successful in war with France, and the colonists in the Revolution against the mother country. The mountain barrier was first crossed along the water gaps, and the fertile, open prairie was then quickly developed; but the great western barrier of desert and mountain held back further advance until after the discovery of gold in California. Our rapid development has depended on the energetic people, wise government, and vast resources; and since the foundation is solid, our prosperity promises to continue.*

Topical Outline and Review Questions.

Topical Outline. — 243. **Early Man.** — Origin by evolution; resemblance to animals; difference from animals; early stages of savagery.

244. **Dependence of Man on Nature.** — Dependence of all mankind; further dependence of civilized man; use of nature by civilized man.

245. **Food Supply.** — Basis of invention; primitive implements; present use; parts of plants eaten; instances; reasons for cultivation; importance of domestication; farming at present; dependence on farmer.

246. **Clothing.** — Need of clothing; materials used; use of skins; vegetable products; animal products; reason for importance.

247. **Shelter.** — (*a*) Primitive shelters: Eskimos; Indians; nomads; sod houses; tropical shelter; caves. (*b*) Building materials: first use; wood; stone; mortar; sun-dried brick; baked brick. (*c*) Fire: need of it; first importance; later uses; result of these uses.

248. **Selection of Homes.** — Two objects in selecting sites; condition of civilized man; instances of sites selected for protection.

249. **Location and Growth of Cities.** — (*a*) Primitive man: reasons for communities; savages; advantages of villages. (*b*) Government: village chief; extension of power; origin of modern government.

(c) European towns: castles; gathering of people about them; present condition. (d) Modern cities: capitals; industries in large capitals; cities at junction of trade routes; on rivers; lake ports; seaports; seaports at mouths of rivers; effect of water power; of mining.

250. **Development of Commerce.** — (a) Exchange: desires of primitive people; methods of gratifying them; early commerce. (b) Greeks; favorable location; colonies; extension beyond Mediterranean. (c) Discovery of new lands: reason for exploration; results. (d) Effects of commerce: exchange; need of money; use of gold; spread of civilization; early writing; alphabet; electricity.

251. **Influence of Man on Nature.** — Life; forest removal, — effect on rivers, on soil; changes in stream courses; irrigation; lakes; work along seacoast; borings; mines; quarrying; tunnels; roads; plowing; independence of man; use of surroundings.

252. **The Spread of Man.** — Resemblance to animals; superior intelligence; use of boats; of clothing and shelter; slow spread; rapid spread; conquest; discovery of new lands; aid of commerce.

253. **Races of Mankind.** — Origin of differences; the races; boundaries; spread of the red race; the black race; the yellow race; the white race.

254. **Man in the Arctic.** — Plant food; animal food in sea; reindeer; Eskimos, — food, dependence on animals, wood, effect of surroundings.

255. **Man in the Tropical Zone.** — Food; ease of meeting needs; effect of climate on civilization; instances of uncivilized people; their condition; possibility of advance.

256. **Man in the Temperate Zone.** — (a) Reasons for civilization: abundant food; need of storing food for winter; need of clothing and shelter; varied climate and land form. (b) Nature of advance: cultivation of crops; domestication of animals; use of implements; of metals; art of building; use of fire.

257. **Man in the Desert.** — (a) The desert itself: comparison with Arctic; domestic animals; nomadic characteristics; effect of desert barrier. (b) On oases: agriculture; cradles of civilization; reasons for development of civilization. (c) Euphrates and Nile: early civilization; its spread; present condition. (d) American Indians.

258. **Influence of Mountains.** — (a) Barriers: races on two sides of Himalayas; protection to India; Alps. (b) Retreats: reasons; Welsh and Scotch; Basques; Switzerland; ancient customs. (c) Mountain people: character; love of freedom; Switzerland.

259. **Influence of Coast Line.** — (a) Closed seas: Mediterranean. (b) Irregular coasts: Greece; Scandinavia. (c) British nation: nearness to sea; irregular coast; fishing; island condition; food supply; colonies; commerce; coal and iron; great importance.

260. **United States.** — (*a*) Favorable conditions: climate; resources; government; coast line; ocean. (*b*) Mountain barrier: first settlements; natives; barrier to westward movement; condition in 1790; Spanish; French; French and Indian war; Revolution. (*c*) Interior: crossing barrier; development of interior; present routes to interior. (*d*) Western barrier: nature; difficulty of crossing; present condition. (*e*) Growth of country: climate; energetic people; resources; government; future.

REVIEW QUESTIONS. — 243. What is believed to be the origin of man? What was his early state?

244. Upon what conditions are all men dependent? In what other ways are civilized men dependent on nature?

245. What simple implements were early used? Why? Why were plants cultivated? What parts are used? Give examples. Of what importance is domestication? Of what present importance is agriculture?

246. What materials are used for clothing? Why are the production and manufacture of materials for clothing so important?

247. What primitive means are employed for securing shelter? How has the use of wood developed? Stone? Clay? Of what use is fire?

248. What considerations have led to the selection of sites for homes? What influences civilized man? Give illustrations of protected sites.

249. Why do men gather in centers? Illustrate. What influence has this on government? What was the condition in Europe? What great European cities are capitals? What else accounts for their growth? What situations especially favor the growth of cities? Give instances. In what several connections is London mentioned?

250. What is the nature of commerce among primitive peoples? How was early commerce carried on? What was the nature of ancient commerce between Asia and Europe? What influence had the Mediterranean? What effect had the Mohammedans? On what does the use of money depend? Why is gold used? State other effects of commerce.

251. State some of the ways in which man influences nature: (*a*) life; (*b*) rivers; (*c*) seacoast; (*d*) the land.

252. Compare and contrast man's spread with that of animals. In what ways has his spread been accomplished? Give illustrations.

253. What is the cause of differences among men? Name the four races. Where is each mainly found (Fig. 544)? Why are the boundaries not sharp? What about the spread of the different races?

254. What are the sources of food for the inhabitants of the Arctic? How do the Eskimos live? Why may they not advance?

255. What conditions in the tropical zone are unfavorable to civilization? What is the condition of the inhabitants? Can they be civilized?

256. What three conditions have favored advance to civilization in

the temperate zone? How have they aided? In what ways has man learned to call nature to his service?

257. What is the condition of man in the desert? Why are primitive customs preserved? Why were oases favorable to the development of early civilization? Of what importance was this in the Old World? What was the condition in the New World?

258. What are the effects of mountains as barriers? Why are they places of retreat? Give illustrations of the influence of this on language. On customs. What effect have mountains on character?

259. Give instances of the influence of closed seas and irregular coasts. What facts account for the importance of the British nation?

260. What conditions are favorable to the advance of the United States? What were the nature and effects of the barrier west of the coast? Where was this barrier crossed? What was the result? What barrier was found farther west? How has it been overcome? Upon what has our progress as a nation depended?

Reference Books. — SHALER, *Nature and Man in America*, Scribner's Sons, New York, 1891, $1.50; PESCHEL, *Races of Man*, Appleton & Co., New York, 1876, $2.25; LUBBOCK, *Origin of Civilization*, Appleton & Co., New York, 1895, $5.00; KEANE, *Ethnology*, 2 vols., Macmillan Co., New York, 1896, $2.60; *Man, Past and Present*, Macmillan Co., New York, 1899, $3.00; BRINTON, *Races and Peoples*, McKay, Philadelphia, 1890, $1.50; RIPLEY, *Races of Europe*, 2 vols., Appleton & Co., New York, 1899, $6.00; RATZEL, *The History of Mankind*, 3 vols., Macmillan Co., New York, 1896–99, $4.00 a volume; GIBBINS, *History of Commerce in Europe*, Macmillan Co., New York, 1891, $0.90; GUYOT, *The Earth and Man*, Scribner's Sons, New York, 1893, $1.75; MARSH, *The Earth as Modified by Human Action*, Scribner's Sons, New York, 1885, $3.50; MACKINDER, *Britain and the British Seas*, Appleton & Co., New York, 1902, $2.00.

APPENDIXES.

APPENDIX A. REVOLUTION OF THE EARTH.

1. Apparent Movements of the Sun. — In addition to the daily rising and setting of the sun there is a slower change in its position which can be detected by noting the point of sunrise or sunset for a week or two. In the north temperate zone, the sun rises exactly in the east and sets due west on March 21 and September 23. From March to September sunrise and sunset are north of true east and west, and the days are longer than the nights. But from September to March the sun rises and sets south of due east and west, and the nights are then longer than the days. The midday sun also changes in position. It is higher in summer than in winter, but is always in the southern half of the heavens. In the southern hemisphere the same changes occur in the opposite season; but there the midday sun is always in the northern half of the heavens.

2. Experiment to Illustrate Revolution. — One or two simple experiments will aid in a better understanding of the way in which revolution (p. 5) causes these apparent movements of the sun. Place two balls in a tub of water (Fig. 548), one in the center to represent the sun, the other off to one side to represent the earth. The water surface represents the *plane of the ecliptic*, or the plane in which the earth moves in its revolution around the sun. If the earth ball is moved around the central ball, its path will represent the orbit of the earth in its revolution.

A needle inserted in the earth ball represents the position of the earth's axis. When the ball is so placed that the needle projects straight up into the air, the axis of the ball is perpendicular to the water surface; if the axis of the earth were in a similar position, it would be perpendicular to the plane of the ecliptic. Now turn the earth ball until the needle is inclined as in Figure

548, which is the same angle as that at which the earth's axis is inclined. The earth is inclined $66\frac{1}{2}°$ to the plane of the ecliptic, or $23\frac{1}{2}°$ to a perpendicular from that plane.

Float the earth ball around the central ball, always keeping the needle axis inclined at the same angle, and you will see quite clearly in what position the earth moves around the sun.

Position 1 (Fig. 548), with the needle pointing *toward* the central ball, may represent the earth's position in summer when the North Pole points toward the sun. In the ball on the opposite side of the tub (3), the needle is inclined *away from* the sun ball, as the North Pole is in winter; but the other end of the needle, or, as we may call it, the South Pole, is then inclined toward the sun ball. Halfway between these summer and winter positions (2 and 4) the axis is inclined neither toward nor away from the sun. These points represent spring and autumn.

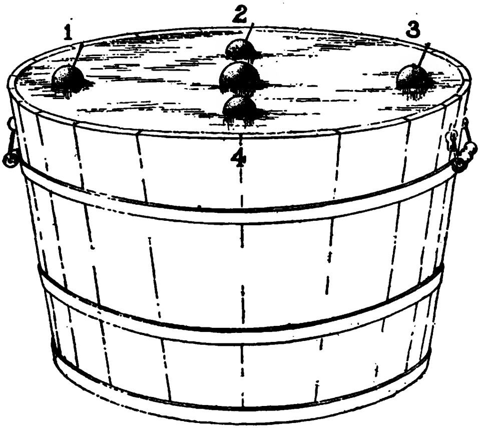

FIG. 548.—To illustrate revolution of the earth.

3. Rotation and Revolution.—The manner in which revolution causes the sun's position in the heavens to change may be understood by another simple experiment. Let a globe or ball represent the earth, and a lamp or candle the sun. Carry the globe in a circular path around the light, being careful to always keep the axis inclined at the same angle.

When the position is that of summer, the full rays of the lamp illuminate the northern half of the globe and reach beyond the pole. So in the case of the earth, when it has reached the summer position in its orbit, the sun's rays reach beyond the North Pole, and illuminate all the space within the Arctic Circle (Fig. 549).

This circle is located 23½° from the pole because the sun's rays of midsummer (June 21) reach that distance beyond the North Pole. They reach that far because this is the amount that the earth's axis is inclined.

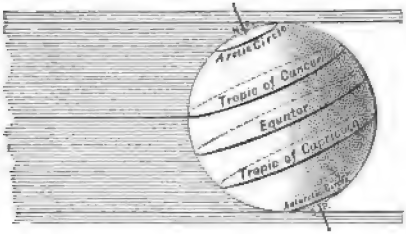

FIG. 549. — Position of the earth June 21.

Now rotate the globe, and you will see that all points within 23½° of the pole are lighted throughout the entire rotation. The same is also true of the earth. This makes it clear why, on the longest day, June 21, every point within the Arctic Circle has sunlight for the full 24 hours (Fig. 550).

Still holding the globe in this position, observe the conditions at the opposite end of the axis, or the South Pole. Even when the globe is rotated, no light reaches that portion. This is also true of the earth in summer, for then the midday sun just barely appears on the Antarctic Circle, 23½° from the South Pole. All within that circle is dark, even at midday.

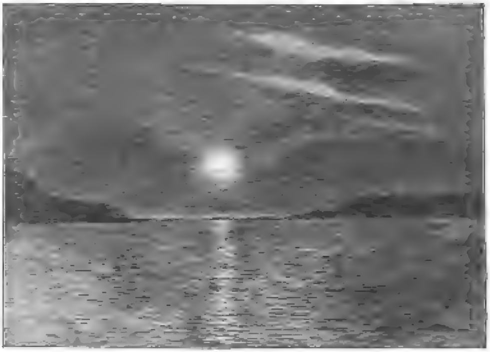

FIG. 550. — The sun at midnight in the Arctic in summer when the region within the Arctic circle is lighted during the entire rotation.

Moving the globe to the opposite, or winter, position (3, Fig. 548), with the North Pole inclined away from the lamp, conditions are reversed. All is darkness within the Arctic Circle, while all within the Antarctic Circle is bathed in light (Fig. 551). This is the earth's condition in winter. Thus, each year as the earth revolves, there is a season of darkness and one of light around each pole.

If the globe is now placed in the position of spring or autumn (2 and 4, Fig. 548), the light will exactly reach each pole. The half of the polar region that faces the lamp is lighted, the half away from it is in darkness; but by rotating the globe the dark side is turned toward the light. When the earth reaches a corresponding position in its orbit, it is divided into a dark and a light half by a plane passing from pole to pole (Fig. 552). At these times, the *equinoxes* (equal nights), all over the earth day and night are each 12 hours long. One period is called *vernal* (spring) *equinox*, the other *autumnal* (autumn) *equinox*.

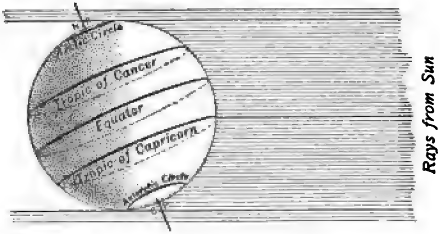

Fig. 551. — Position of the earth December 21.

During the equinoxes, when the sunlight just reaches each pole, the midday sun is directly above the equator. After December 21, in all parts of the earth, the sun appears to be slowly moving northward, and the sunlight slowly creeps over the curvature of the earth into the Arctic. After the earth has passed its summer position, the sun seems, from all points on the globe, to be slowly moving southward, and the sunlight is gradually withdrawn from the Arctic.

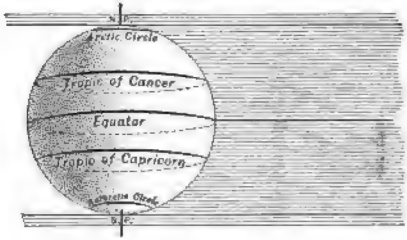

Fig. 552.—Position of the earth September 23.

If the earth's axis were perpendicular to the plane of the ecliptic, there would be no such changes; but, since it is inclined, revolution turns one hemisphere toward the sun for a time, then away from it. These annual changes recur so regularly that, in all the time of human history, there has been no noticeable change.

Suggestions. — (1) Study Sections 2 and 3 at the same time that you are yourself performing the experiments described. (2) Make careful observations of the change in the sun from day to day. On a

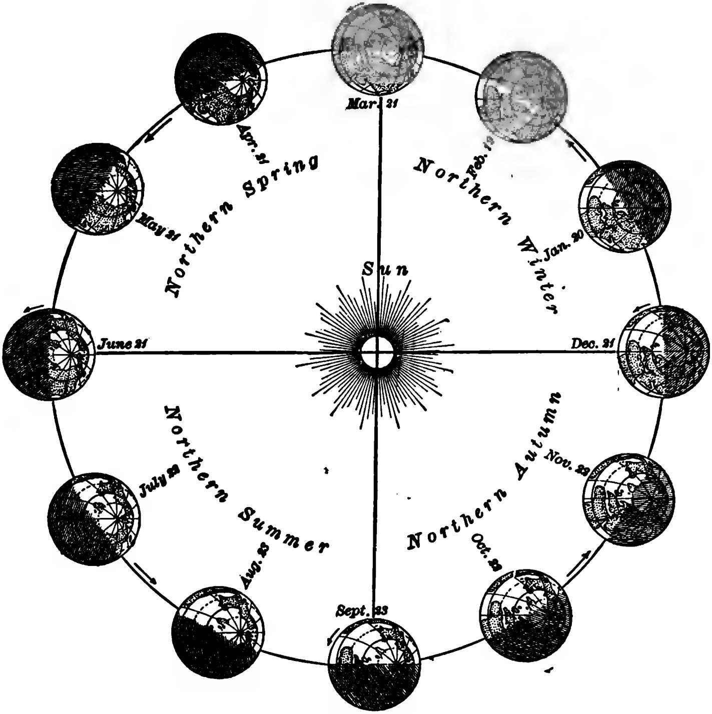

FIG. 553. — To illustrate the revolution of the earth around the sun.

platform, or table, placed where the sun reaches it from morning till night, draw intersecting north-south (p. 419) and east-west lines. Where they cross drive a long knitting needle into the table. Once a week at noon mark on the north-south line the point to which the needle shadow reaches. Also mark the point reached by the shadow just after sunrise or just before sunset. What movements of the sun cause these changes? Observe also the exact place where the sun sets each week. (3) In what direction does your shadow point at noon? In what direction would it point in South Africa? At each tropic, in the middle of March, June, September, and January? At the equator? What is the direction of a shadow at noon in summer in the Arctic? At midnight? Are such shadows longer or shorter than in the temperate zone?

APPENDIX B. LATITUDE AND LONGITUDE.

1. **Latitude.** — The most convenient method of locating points on the spherical earth is by imaginary circles extending in opposite directions. Any point can then be definitely located by the intersection of such circles. These are called circles of *latitude* and *longitude*, names given when the extent of the world was not known, and one direction (longitude) was supposed to be the long direction, the other (latitude) the broad direction.

For measurement of latitude imaginary circles are extended in an east-west direction. The largest circle (about 25,000 miles), the *equator*, extends around the earth midway between the poles. Other circles parallel to this, and called *parallels of latitude*, are located at intervals between the equator and either pole. As their distance from the equator increases, these circles diminish in diameter (Fig. 554) until, at the poles, a circle of latitude is reduced to a point.

For convenience in use the parallels are numbered. From the equator to the north pole there are 90 parallels, numbered as *degrees* (indicated by the sign °); there are also 90 from the equator to the south pole. The equator is called 0° latitude; the north pole, 90° north latitude (abbreviated N. Lat.); the south pole, 90° south latitude (S. Lat.). The Tropic of Cancer is 23½° N. Lat.; the Arctic Circle, 66½° N. Lat.; the Tropic of Capricorn, 23½° S. Lat.; the Antarctic Circle, 66½° S. Lat. Which parallel of latitude is nearest your home?

Since there are 180° from pole to pole there are twice that number, or 360°, in a complete circle extending around the earth across the poles. It is customary to divide circles into 360°. This is a convenient number because it is exactly divisible by so many numbers.

The length of a degree of latitude, that is the distance between two circles, varies slightly because the earth is not a perfect

sphere (p. 3). It is $\frac{1}{360}$ of the circumference. Divide the circumference of the earth (25,000 miles) by 360. At the equator a degree is about 68.7 miles, at the poles about 69.4 miles.

FIG. 554. — To show how the meridians converge at the pole. Trace the 0° meridian to the opposite side of the globe. What is it numbered there?

On a small map of a large area, as a continent, it is impossible to draw every parallel, for the lines would be too close together. Accordingly, every fifth or tenth circle is placed on such a map. But for a map of a small section (Fig. 78) the degrees are too far apart, and additional circles are necessary. For this purpose degrees are subdivided into minutes (indicated ′), and minutes into seconds (indicated ″). There are 60 seconds in a minute of latitude, and 60 minutes in a degree. What is the latitude of your town in degrees, minutes, and seconds?

2. Longitude. — Circles of latitude serve to accurately locate places in a north-south direction; but there is need of location in an east-west direction also. Circles of longitude serve this purpose. These circles all start from the poles, broadening out toward the equator, and are therefore not parallel (Fig. 554). To them the name *meridian* is often applied.

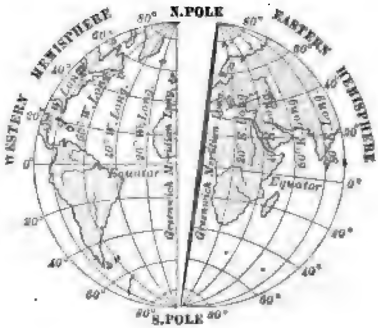

FIG. 555. — The earth cut in halves along the Greenwich meridian.

At the equator a degree of longitude is about equal to a degree of latitude (69 miles),

being $\frac{1}{360}$ of the earth's circumference. In latitude 40°, which is a much smaller circle than the equator (Fig. 554), a degree of longitude, $\frac{1}{360}$ of that circle of latitude, is only about 53 miles. In latitude 60° a degree of longitude is about 34.7 miles; and at the poles, where all the meridians come together, a degree of longitude has no length.

The circles of longitude are numbered as degrees, there being 360 degrees. Since there is no such natural starting point as the equator, there is no general agreement as to where the numbering of meridians shall begin. Most nations, however, have adopted as the 0°, or *prime meridian*, the circle that passes through the Greenwich Observatory, just outside of London. From this meridian the circles are numbered up to 180° both east and west. New York is 74° W. Long.; Jerusalem is 35° E. Long. What is the nearest meridian to your town?

Degrees of longitude are divided into minutes and seconds, as degrees of latitude are. What is the longitude of your home in degrees, minutes, and seconds?

FIG. 556. — Map to illustrate standard time in United States. The meridians 75°, 90°, 105°, and 120° extend through the middle of the four time belts. The irregular boundaries are due to the fact that railways have chosen convenient points on their lines to make the change.

3. Longitude and Time. — Rotation causes the sun to appear to pass completely around the earth in 24 hours. That is, it passes over 360° in 24 hours; and, dividing 360 by 24, we find that it passes over 15° in an hour. From this it is evident that places 15° apart will have just one hour's difference in time. Formerly, places in United States kept local or solar time, and even neighboring cities might have a different time. This caused so much inconvenience that it was agreed to adopt a *standard time*, by which the time changes one hour for every 15° of longitude. Now in traveling across the continent one need change his watch only three times (Fig. 556).

If longitude may be used to determine time, it is evident that time may be used to determine longitude. Ships crossing the ocean are able in this way to determine their position. They start with an accurate clock, or *chronometer*, set to Greenwich time. By means of an instrument, the *sextant*, an officer observes the sun to determine the local noon, that is, the time when the sun has reached its highest position. Comparing this local time with that of the chronometer, it is easy to tell just how many minutes' difference there is between Greenwich time and that where the ship is. Knowing that one hour's difference means 15° of longitude, the longitude of the ship is readily determined.

Suggestions. — (1) To understand the need of circles of latitude and longitude, try to locate New York City without these. Do the same by use of latitude and longitude. (2) By tying the ends of strings together make three circles so that one will fit over the equator of a globe, one over parallel 45°, and one over parallel 60°. Make three other circles for meridians and place them on the globe, one over 0° longitude, one over 60° west longitude, one over 120° west longitude. With ink, mark on each of the latitude strings the place where two of the meridians cross. Take the strings off, and measure the diameters of each. How do the diameters of the meridian strings compare with the equator string? How do the three latitude strings compare in diameter? Measure the distance between the ink marks made on the latitude strings. How do these distances compare? This shows how the length of degrees of longitude varies. (3) Get a local surveyor to explain and illustrate the method of determining latitude and longitude. (4) Recall your previous study of standard time (see Second Book of Tarr & McMurry's Geographies, p. 116). If the earth were flat, what would be the effect on time? To answer this, imagine a table top to represent the earth. Raise a lighted candle up to the edge to represent the rising sun. How much of the table do the rays reach at once? Is any more of the table reached as the candle is raised higher? Now, to represent part of the globular earth, place a curved object on the table top; for example, a large sheet of cardboard or blotting paper, resting on books or dishes. How much of this curved surface is lighted when the candle is raised? Is more lighted as the candle is raised higher?

APPENDIX C. COMMON MINERALS AND ROCKS.

MINERALS.

This appendix should be studied with an accompanying use of mineral specimens. Each mineral should be carefully examined to note its color, hardness, cleavage, luster, and crystal form. The text may be referred to, but each student should have a set of specimens and be expected to find the features visible.

A MINERAL may be defined as a single element, or two or more elements chemically combined, forming a part of the earth's crust. Some, like sulphur, consists of one element; but most minerals are formed by a combination of several. For example, quartz is made of silicon and oxygen; one of the feldspars contains silicon, oxygen, aluminum, and potassium.

There are about 2000 known minerals, of which only one or two hundred are abundant, while less than a dozen are common in most rocks. The more important of the rock-forming minerals are described below.

1. **Common Rock-forming Minerals.** — *Quartz.* — This, the most common of minerals, is present in many rocks and soils. It is made of silicon and oxygen, forming silica (SiO_2). These elements are so firmly united that quartz does not decay; but it is slightly soluble in underground water. It has a glassy appearance, or *luster*, and varies in color from clear glassy to milky white, blue, rose-colored, red, and variegated. Agate, opal, jasper, and chalcedony are varieties of silica. It is so hard that it will scratch glass, but is brittle and easily broken, having a shelly or *conchoidal fracture*, like glass. When it crystallizes it takes the form of a six-sided (hexagonal) prism terminated by a six-sided pyramid.

The Feldspars. — There are a number of kinds of feldspar, each formed by the union of several elements, and all nearly as hard as quartz. Crystals are not common. *Cleavage planes*, extending through feldspar, cause it to break along smooth faces. Unlike

quartz, feldspar is not soluble. When exposed to air and water, however, it decays, becoming dull and whitish; and, if exposed long enough, the hard mineral crumbles to a whitish clay, or *kaolin*. Many soils contain decayed feldspar, and some of the best pottery clays are kaolin. Thus, though insoluble and nearly as hard as quartz, its decay makes feldspar less durable.

Calcite (calcium carbonate), like quartz, varies greatly in color. It often has a perfect crystal outline; and since it has cleavage in three directions, when broken it is apt to take the form of a rhomb. It has a pearly luster. Unlike quartz and feldspar, calcite is so soft that a knife readily scratches it. Moreover, it is one of the most soluble of common minerals; and the cleavage planes afford opportunity for water to enter and dissolve the mineral. For these reasons a calcite rock is far less durable than one made of feldspar and quartz.

The mineral *dolomite* resembles calcite; but it is less soluble, and has a different chemical composition. Calcite contains calcium, carbon, and oxygen, and is, therefore, carbonate of lime ($CaCO_3$); dolomite has magnesium in addition, and is, therefore, magnesian carbonate of lime ($(CaMg)\ CO_3$).

The Micas. — There are a number of different minerals belonging to this group, all having a complex chemical composition. Some are black, some colored, and some so colorless that they are used in stove doors as "isinglass." Two of the most common forms are *biotite* and *muscovite*, the former dark colored, the latter light. All are easily scratched with a knife, and all have such remarkable cleavage that they readily split into thin sheets. Some micas decay readily; but others so resist decay that they occur as shiny flakes in soils and some rocks, such as sandstones and shales.

Hornblende is a black mineral of complex chemical composition, common in some granites and lavas. It is hard, has a bright luster, is often crystalline, and has well-defined cleavage. When exposed to air and water it decays, one of the products being an iron compound which stains the rock. Iron is one of the elements in this mineral.

Augite, found in many lavas, resembles hornblende in several respects, and in small grains is difficult to distinguish from it. Its chemical composition, crystal form, and the angle at which

the cleavage faces meet are different, and the color is dark green instead of black. Like hornblende it decays readily.

Iron Ores. — Small quantities of iron are present in many minerals and rocks, and the yellow and red color of soils is due to iron stain. Among the iron minerals are several which are of value as ores.

Magnetite, a compound of iron and oxygen (Fe_3O_4), is black, hard, heavy, usually crystalline, and has a metallic luster. A magnet will attract the grains. *Hematite* (Fe_2O_3), another oxide of iron, is red and either earthy, crystalline, or in smooth, rounded masses. Like other iron ores it is heavy. The red coloring of soils is due to a hematite stain. *Limonite* is yellow, and common iron rust and the yellow color of soils are due to this mineral. It is an iron oxide with water, or a hydrous oxide ($2Fe_2O_3\ 3H_2O$). It is easy to determine an ore of iron by scratching it on a piece of white quartz, or of broken china. Magnetite gives a black streak, hematite red, and limonite yellow.

Siderite, the carbonate of iron ($FeCO_3$), is a heavy brownish mineral, resembling calcite in general appearance. *Iron pyrite*, or pyrites, the sulphide of iron (FeS_2), is not useful as an ore. It is a hard, heavy, golden yellow mineral, sometimes mistaken for gold, and hence called "fool's gold." It often occurs in perfect cubical crystals.

Gypsum, the sulphate of lime, occurs in small grains in many rocks, and sometimes in beds. It is so soft that it can be scratched with the finger nail; and, being soluble, is often present in "hard" water. The color varies, but is often white. Sometimes it is well crystallized, then having such perfect cleavage that it splits into thin flakes; but, unlike mica, the flakes are not elastic.

Minerals in Rocks. — The tables (pp. 410–413) show that the common rocks are made chiefly of the minerals described above. Other minerals, while abundant in some localities, are relatively rare in the rocks of the earth; but some of the rarer minerals, such as the ores of gold, silver, copper, etc., are of great value to man.

ROCKS.

2. Classification of the Common Rocks. — Rocks are mixtures of minerals, and are not usually of definite chemical composition. They may be classified in three great groups: —

(1) *Sedimentary rocks*, most of which were deposited in water; (2) *Igneous rocks*, which were once molten; and (3) *Metamorphic*

rocks, which have been altered from some previous state by heat, pressure, and water. A few of the most common are described below.

3. Sedimentary Rocks. — *Fragmental or Clastic Rocks.* — By the disintegration of rocks, fragments of all sizes, from clay to bowlders, are detached. When assorted by water these are deposited in layers (p. 33), the pebbles forming *gravel beds*, the sand, *sand beds*, and clay, *clay beds*. Rock fragments may also be brought by glaciers, by wind, and by volcanic explosions, which supply ash and pumice. These fragmental, or clastic, materials may be cemented into solid rock by the deposit of mineral substances carried by underground water (p. 39).

Consolidated gravel beds, called *conglomerates*, are composed of whatever minerals were in the rocks from which the pebbles are derived. Consolidated sand beds, or *sandstones*, usually consist of small quartz grains, quartz being the most indestructible of common minerals. Some sandstones are well cemented and firm, others friable; and iron oxide cement often gives to them red, yellow, or brown colors.

A well-cemented sandstone or conglomerate, with much quartz in it, is one of the most durable of rocks, resisting denudation so well that it forms peaks and ridges, as in the Appalachians. Since quartz does not decay and produce plant food, as feldspar and many other minerals do, sandstones make poor soils.

Shale, the most common clay rock, varies in color from black to blue or light gray. Because of the presence of large numbers of flattened particles, often small mica flakes, it splits readily along the bedding planes. Shales split so easily, and are so soft, that they readily disintegrate, and among mountains are, therefore, usually found in the valleys. Soils produced by the decay of shale are much more fertile than sandstone soils.

Chemically formed Rocks. — The decay of minerals produces many substances which underground water dissolves. After being carried for a while, some may be deposited. For example, carbonate of lime is being deposited as *stalactites* in caverns (p. 60) and as *calcareous tufa* around the Hot Springs of Yellowstone Park (Fig. 243). On the coast of Florida and in Great Salt Lake it is also being precipitated in small, rounded, or *oolitic grains*

(p. 163). *Salt* is being deposited on marshes bordering Great Salt Lake and the Caspian Sea; and, by the drying up of salt lakes, as in western United States, *gypsum* has been precipitated. Deposits of silica around the geysers of Yellowstone Park form *silicious sinter* (Fig. 244); and *bog iron ore* is being accumulated where certain spring waters, on reaching the air, are forced to deposit iron. Underground water has deposited many veins of valuable metal in fissures in the crust (p. 132).

Sedimentary Rocks.

Origin.	Name.	Composition.
Fragmental, or clastic rocks.	Gravel beds.	Made of pebbles derived from other rocks.
	Conglomerates.	Consolidated masses of pebbles.
	Sand beds.	Finer fragments, usually quartz grains.
	Sandstones.	Consolidated sand beds.
	Clay beds.	Disintegrated feldspar, hornblende, etc.
	Shale.	Consolidated clay beds, splitting readily.
Chemically formed rocks.	Stalactite, oolite, calcareous tufa.	Carbonate of lime, deposited in water.
	Iron deposits.	Some ores of iron, especially bog iron ore.
	Silicious sinter.	Silica deposited from water.
	Salt.	Sodium chloride.
	Gypsum.	Sulphate of lime.
Organic rocks.	Most limestones.	Carbonate of lime, made of shells, etc.
	Coal (bituminous, lignite, peat).	Made of plant remains.

Organic Rocks. — Carbonate of lime, dissolved in water, supplies many animals with materials for shells, or limy framework. Where such animals are abundant, as in coral reefs (p. 217), their limy remains often accumulate as thick beds of *limestone.* Many such beds have been raised to form part of the land. Limestone, being both soft and soluble, is worn away to form lowlands; and, since it is rich in plant food, it forms a fertile soil. This is illustrated in the broad, fertile limestone valleys which extend among the mountains of New England and New Jersey, and thence through the Shenandoah valley of Virginia

to Tennessee. *Dolomite* is not so easily worn, and, when very massive, sometimes forms mountains. One very rugged section of the Alps is known as the Dolomite Alps.

Remains of plants accumulate in swamps, as in *peat* bogs (p. 168), where the water retards decay. When such swamp deposits have been covered with beds of other rocks, they gradually lose their water and gases, and change to *coal* (p. 170). The early stages of this change form *lignite*, later stages *bituminous* coal.

4. Igneous Rocks. — These rocks, which have risen in a melted condition from within the earth, have cooled either on the surface, as near volcanoes, or below the surface as *intruded* masses in the crust (p. 126). In the latter case, the overlying blanket of strata has allowed the lava to cool so slowly that the minerals have had opportunity to grow to fair size, giving these intruded rocks a coarse crystalline structure. In many places denudation has worn the surface down to these intruded igneous rocks.

Granite (Fig. 33). — Granite is the most common intruded igneous rock. Of what minerals is it composed (see table p. 412)? The structure is so coarse that the different mineral grains are plainly seen and easily distinguished. The color of granite varies according to the color of the feldspar, being commonly light and either gray, grayish green, red, or pink. It is a valuable building stone, and is one of the hardest and most durable of rocks, resisting destruction so well that, in the wearing down of mountains, it is commonly left standing as peaks.

Syenite, the rock of which the Egyptian pyramids are made, resembles granite, but has no quartz. Gabbro, norite, and anorthosite, found in the Adirondacks and in Canada, are hard, intruded igneous rocks, less common than granite.

Diorite and *Diabase* are dark-colored igneous rocks without quartz, the color being due to dark-colored minerals, especially hornblende, augite, and mica. Diabase, also called *trap,* is often so fine grained that the minerals cannot be distinguished without a microscope. The Palisades of the Hudson and the trap hills of New Jersey and the Connecticut valley are diabase.

Rhyolite, trachyte, andesite, and *basalt* (see table) are among the most common lavas erupted from volcanoes. The first two

SUGGESTIONS. — (1) Collect minerals from your neighborhood and study them. *Dana's Minerals and How to Study Them* is a good book of reference. (2) Collect rocks from the ledges, bowlders, quarries, and stone yards. If you live in a part of the country reached by the ice sheet (Fig. 270), you will find a varied store of rock specimens in the gravel banks. See how many kinds you can collect. Study their characteristics; place them in one of the three groups and, if possible, give them their proper names. The teacher can systematize this work and make it of great disciplinary value. (3) Place pieces of quartz, feldspar, and calcite in weak hydrochloric acid. Which is attacked by it? Water in the earth is often weakly acid, and in this state attacks minerals. (4) Grind up some mica, mix with sand, and stir in water. After the sediment has settled, notice the position of the mica flakes. It is for this reason that shales split readily along the bedding planes. (5) To which of the three groups do the rocks of your neighborhood belong? What kind or kinds do you find? Of what are they made? Are they hard or soft? Do they make rich or poor soil? If your home is in a valley, see if the rocks on the hills are different. What are the differences? Do they help account for the hills and valleys?

TABLE FOR GUIDE IN STUDY OF MINERALS.

NAME.	HARDNESS.	COLOR.	SPECIFIC GRAVITY.	CRYSTAL FORM.	CLEAVAGE.	FRACTURE.	LUSTER.	OTHER FEATURES.
Quartz.	7	Transparent.	2.6	Hexagonal.	None.	Conchoidal.	Vitreous.	
Calcite.								
Etc.								

Reference Books. — DANA, *Minerals and How to Study Them*, Wiley & Sons, New York, 1895, $1.50; KEMP, *Handbook of Rocks*, D. Van Nostrand Co., New York, 2d ed., 1900, $1.50.

APPENDIX D. GEOLOGICAL AGES.

WHILE it is impossible to tell the age of the earth in years (p. 45), geologists have divided the strata into stages, or periods, and have determined their *relative* age. This is made possible by the fossils the strata contain. For example, there was a time when no animals higher than fishes lived on the earth; and if strata contain remains of birds, it is certain that they were not deposited in those ancient times. Careful studies of fossils, in all parts of the earth, have so clearly revealed the history of the development of life that, on examining the fossils in a rock, geologists can now tell in what period it was formed. To the different periods names have been given, some of the most common of which are placed in the following table:

<table>
<tr><td rowspan="3">CENOZOIC TIME.
(Age of Mammals.)</td><td colspan="2">Pleistocene, or Quaternary.</td><td>Man assumes importance, particularly in upper part. Glacial period in first half.</td></tr>
<tr><td>NEOCENE.</td><td rowspan="2">Tertiary.</td><td rowspan="2">Mammals develop in remarkable variety, and to great size, while reptiles diminish.</td></tr>
<tr><td>EOCENE.</td></tr>
<tr><td rowspan="3">MESOZOIC TIME.
(Age of Reptiles.)</td><td colspan="2">Cretaceous.</td><td>Birds begin to be important; reptiles continue; and higher mammals appear; land plants and insects of high type.</td></tr>
<tr><td colspan="2">Jurassic.</td><td>Reptiles and amphibia predominate.</td></tr>
<tr><td colspan="2">Triassic.</td><td>Amphibia and reptiles develop remarkably; low forms of mammals appear.</td></tr>
<tr><td rowspan="4">PALEOZOIC TIME.
(Age of Invertebrates.)</td><td colspan="2">Carboniferous.</td><td>Land plants assume great importance.</td></tr>
<tr><td colspan="2">Devonian.</td><td>Fishes are abundant.</td></tr>
<tr><td colspan="2">Silurian.</td><td>Invertebrates[1] prevail.</td></tr>
<tr><td colspan="2">Cambrian.</td><td>No forms higher than invertebrates.</td></tr>
<tr><td>In part AZOIC TIME.
(No fossils known.)</td><td colspan="2">Archean.[2]</td><td>Mostly metamorphic rocks; perhaps, in part, original crust of earth.</td></tr>
</table>

[1] Invertebrates continue abundant to present time, but are of different kinds. Fishes, which began in the Silurian, continue, though with many changes, to the present time.

[2] Upper part sometimes called Algonkian.

APPENDIX E. TIDES.

The full explanation of tides is considered too difficult and complex for statement in so elementary a book. It is known that they are caused by the attraction of gravitation which both sun and moon are exerting on the earth; but the moon is more effective in this than the sun.

This pull of gravitation draws the ocean water toward the moon (Fig. 557), producing a wave which follows the moon across the oceans. A second high tide is formed on the opposite side of the earth. In this way the ocean is distorted into a somewhat elliptical form. If the earth were all water, the attraction of the moon would change it to an ellipse; and, as the earth rotated, the form of the ellipse would constantly change to keep its axis pointing toward the moon.[1] That is to say, two waves would constantly be passing around the earth, following the moon. To understand this shape attach a rubber ball to the floor and, by a string on the upper side, pull until the ball loses its spherical shape.

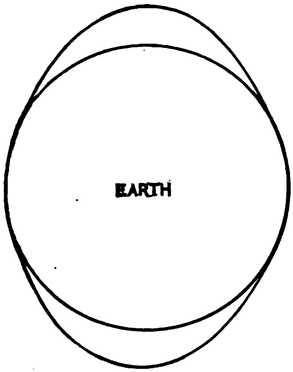

Fig. 557. — Distortion of ocean by attraction of moon, — distortion being greatly exaggerated.

Tidal waves are produced by the sun in the same way as by the moon; but, although the sun is so much larger than the moon,

[1] There is more to the tidal explanation than the mere pull of gravitation; there is also the effect of centrifugal force. However, unless the teacher, because of special interest, wishes to enter into a full study of tides, it does not seem well to introduce this complex question.

its greater distance makes its tide-producing effect less. The solar tides are, therefore, only about one third as great as the lunar tides. Thus, at all times, there are four tidal waves in the oceans, two formed by the moon, and two smaller ones by the sun. In each pair one is on the opposite side of the earth from the other.

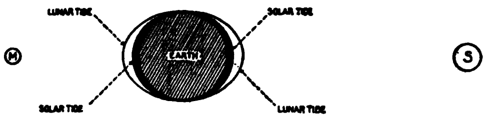

FIG. 558. — To illustrate cause of spring tides — distortion being greatly exaggerated.

At full moon (Fig. 558) the sun and moon are nearly in line. They are then pulling so nearly together that the solar and lunar tides combine, causing an uncommonly high tidal range, known as *spring tide.* At new moon, the sun and moon are again nearly in line, and spring tides are again formed. During the quarters (Fig. 559), on the other hand, the high tides formed by the moon occur where low tides are caused by the sun; consequently the tidal range is much less. These tides of low range are called *neap tides.* Each lunar month, that is every 29½ days, there are two spring and two neap tides.

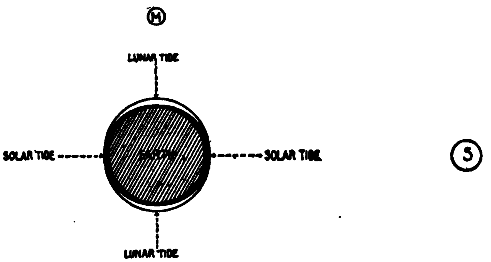

FIG. 559. — To illustrate cause of neap tides.

Another cause for variation in tidal range is the distance of the moon. The moon revolves around the earth in an ellipse, and when it is nearest to the earth, or in *perigee*, the lunar tide is higher than when it is farthest, or in *apogee*. Because of these variations in the relative position of sun and moon, and in the distance of the moon, the tidal range varies greatly. There is also an irregular variation due to wind (p. 271), which sometimes piles the water up in bays, causing it to overflow wharves and low land that the tide itself never reaches.

APPENDIX F. MAGNETISM.

In the United States, as in other regions, a bar or needle of magnetized steel, so suspended that it freely swings horizontally, will point north and south. An instrument having such a needle is a *compass*. Throughout most of the country the compass needle points a little to one side of a true north and south line. In central western Greenland the needle points westward, in northern Greenland, southwestward. The place toward which the compass needle points is known as the *north magnetic pole*, and is located north of Hudson Bay and west of Baffin Land. Within the Antarctic Circle, between New Zealand and the South Pole, there is a similar region known as the *south magnetic pole*.

It is because of these centers of magnetism that the compass is so valuable that sailors depend upon it for determining the course of their ships, and the steersman always has one in plain sight. In the Arctic the compass is much less useful, for, though nearer the magnetic pole, the needle is less sensitive and more easily deflected by outside influences, such as the presence of iron.

The reason for this fact is that the cause for the attraction of the needle lies beneath the earth's surface. This is proved by so suspending a needle that it will freely swing, or dip, vertically. At the magnetic pole, the needle of such a *dip compass* points directly downward; near the equator it swings horizontally; part way between the pole and equator it points toward the earth at an angle. From this it is evident that, the nearer one goes to the magnetic pole, the stronger becomes the downward attraction and the weaker the horizontal pull, and, therefore, the less useful the compass.

Along a line extending from South Carolina to Lake Superior, *magnetic north*, or north by the compass, is the same as true north; that is, the compass points toward the north pole. East of this line the compass points to the west of true north, northern Maine showing a difference between magnetic and true north, or a *declina-*

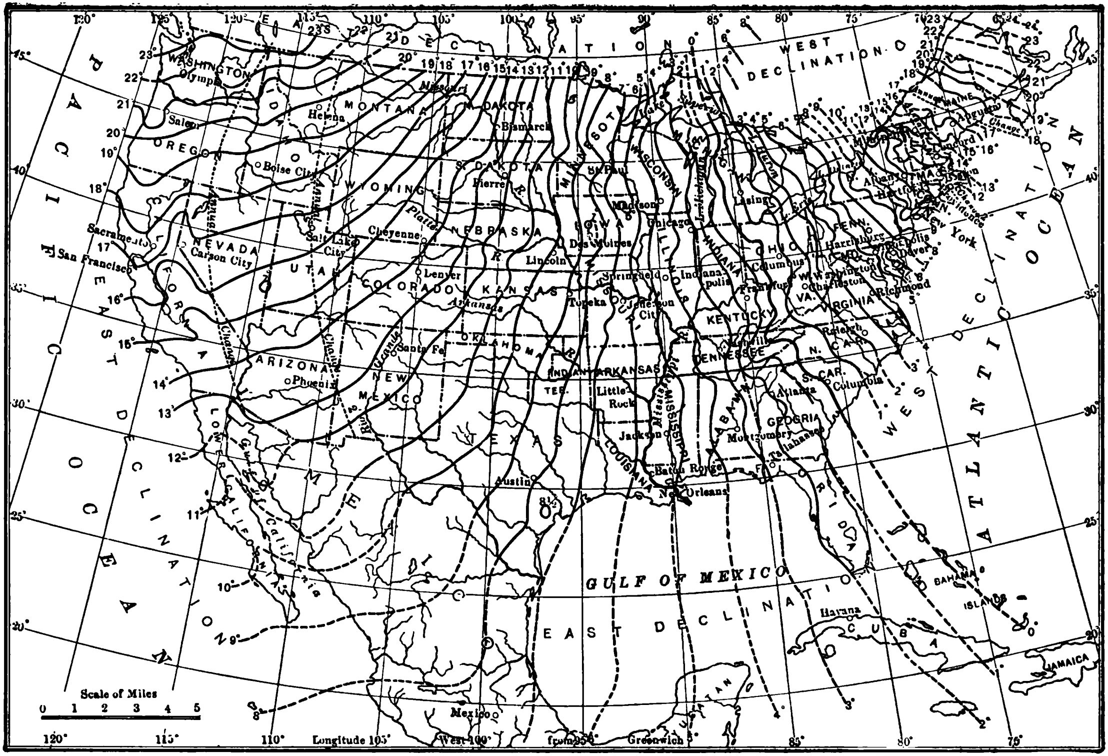

FIG. 560. — Isogonic map of United States, showing the amount of declination for 1901.

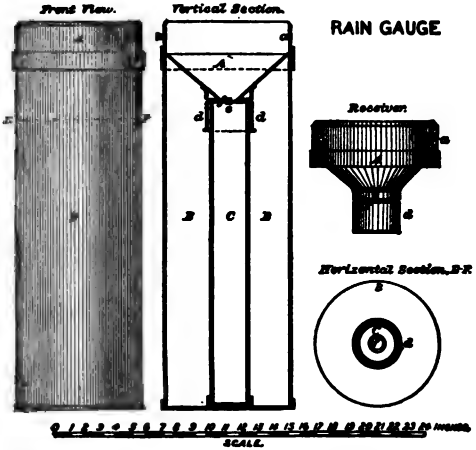

Fig. 561. — Rain gauge. *B*, outer cylinder; *C*, inner cylinder; *a*, *a* (and small left-hand figures), the funnel.

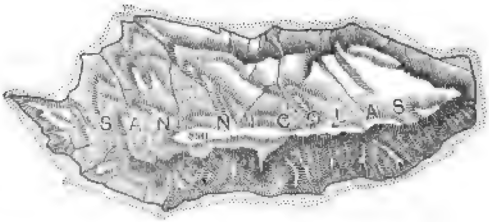

Fig. 562. — Hachure map from one of the United States Coast Survey charts.

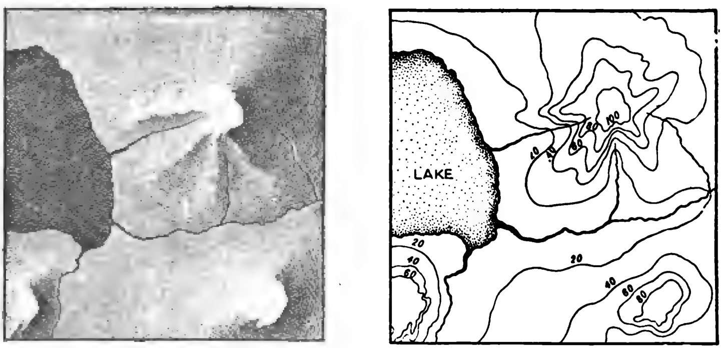

Fig. 563. — To illustrate the meaning of contours. On the left is a model; on the right the same topography is represented by contours.

tion, of 21°. West of the line of no variation, or no declination, the needle points to the east of true north, in northern Washington reaching an east declination of 23°. A map showing lines of equal magnetic declination is an *isogonic map* (Fig. 560).

The amount of declination slowly changes, so that a map made for one year is not strictly accurate for the next year; but the change is so slow that a long time is necessary to produce a marked difference. The cause for these changes, and even the cause for the magnetism of the earth, is unknown. It is some condition within the earth, far from the surface, possibly in some way connected with the heated interior. All that is positively known is that, for some reason, the earth acts as a great magnet.

The *aurora borealis*, or northern lights, is in some way connected with this magnetism. A similar phenomenon, the *aurora australis*, is found in the southern hemisphere. The aurora is not common in the United States, though sometimes it becomes visible, and even vivid. The northern sky is then aglow with an arch of strange light, with streamers darting to and fro. In the far north the aurora becomes much more vivid, and may be seen night after night. The cause of the aurora is unknown, though it seems to be due to faint electrical discharges in the upper air, resulting from some influence of the earth's magnetism.

Suggestions. — (1) Learn to read a compass (a small one is quite inexpensive). Determine the true north and south line. This can be done by setting up two poles in line with the north star. With a compass, observe the difference between true and magnetic north. (2) Place a bar of iron near a compass. Is the needle disturbed? Try the effect of a magnet. (3) If you have ever seen an aurora, describe it. Have you ever read a description of one in a book of Arctic travel?

APPENDIX G. METEOROLOGICAL INSTRUMENTS.

1. Thermometers. — The ordinary thermometer is a sealed glass tube with a cavity of small diameter, ending below in an expansion, or bulb, in which there is mercury. The mercury can rise and fall freely in the tube because there is no air in it. The principle of the thermometer is that liquids, like mercury, expand and require more space when warmed, but, when cooled, contract and take up less space. As the temperature changes, therefore, the mercury in the bulb causes a tiny thread of mercury to rise and fall in the tube. Other liquids may be used; in fact, alcohol is used when thermometers are to be exposed to cold greater than the freezing point of mercury (– 40°).

Thermometers are graduated in degrees, the division commonly used in America and England being the Fahrenheit (Fahr.) scale. In this, the boiling point of water is placed at 212° and its freezing point at 32°. This is not nearly so simple a scale as the Centigrade (Cent.) which is commonly used on the continent of Europe. In this, the freezing point is placed at 0° and the boiling point at 100°. To convert Centigrade to Fahrenheit, multiply by 1.8° and add 32°. Thus 10° Cent. equals 50° Fahr. (10° × 1.8° = 18° + 32° = 50°).

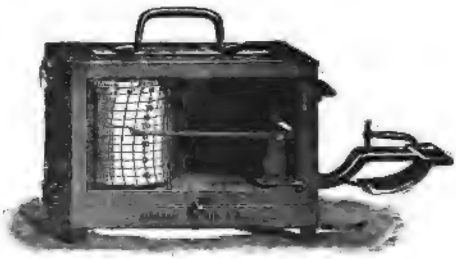

Fig. 564. — A thermograph.

Metals also expand when warmed and contract when cooled. Because of this fact, thermometers may be made of metal strips connected with a hand that moves over a graduated dial. Such thermometers may sometimes be seen in front of city stores. A metal thermometer may also be connected with an arm, bearing a pen, which is moved as the temperature changes. This pen may be so placed as to press against a piece of paper on a cylinder, revolved by clockwork. As the pen rises and falls, while the

cylinder regularly revolves, it writes a record of temperature changes for every minute of the day. Such a self-recording thermometer is called a *thermograph* (Fig. 564).

2. Barometers. — The weight, or pressure, of air will push liquid up into a tube having a vacuum in the top. It will push the liquid up until a column is formed that equals the weight of the air column pressing on it. It is because of this air pressure that water is pushed up from a well into the tube of a pump. The stroke of the pump exhausts air from the tube, thus tending to make a vacuum, into which the water may be pushed by the air pressure. Since a column of water about 30 feet high balances the air pressure, an ordinary pump could not possibly raise water from a fifty-foot well.

Years ago water, in tubes over 30 feet long, was used to measure air pressure. Mercury is now employed because it is so heavy that a column only thirty inches high balances the air pressure. An instrument containing such a mercury column is called a *barometer.*

Any one can make a rough barometer with a glass tube 35 inches long, sealed at one end. Fill it with mercury, and invert it, with the open end in a small dish of mercury, being careful not to allow the mercury to spill. The mercury will fall a few inches, and air pressure will keep it there. By fastening it to a standard to keep it upright, one may watch the mercury rise and fall from day to day. A scale of inches and tenths of inches may be marked on the glass with a piece of quartz or a glazier's diamond; or on the piece of wood to which the tube is fastened. By comparison with a barometer the scale may be made exact.

Ordinary mercury barometers are graduated in inches and tenths of inches, and a scale, called a *vernier,* enables readings to hundredths of inches. As storms come and go the air pressure varies, and with these changes the height of the mercury column changes. When the air is heavy the barometer column is high, and there is a *high barometer;* when the air is light the barometer column is low, and there is a *low barometer.* For example, 30.1 inches is a high barometer; 29.3 is a low barometer.

Since there is less air (and therefore less pressure) above highlands than lowlands, the barometer is low on highlands and high on lowlands. As this difference in pressure varies quite regu-

larly, a barometer may be used to measure elevation; for a change of an inch in the mercury column represents a difference in elevation of a certain number of feet.

A mercurial barometer is too cumbersome, and too easily injured, to be carried about; therefore, for measuring elevations, an *aneroid barometer* is commonly used. An aneroid, which is so small that it may be carried in the pocket, has a metal diaphragm inside of a metal case. Differences in air pressure cause this diaphragm to move, and this movement is communicated to a hand which moves over a dial (Fig. 565). Since the dial is graduated in feet, one can tell at a glance how high he has climbed.

FIG. 565. — Aneroid barometer, graduated in feet (outside) and inches (inside).

One serious disadvantage in the use of the aneroid is that it is affected by *all* changes in air pressure. Thus, if a storm passes while the aneroid is being used to measure an elevation, the change in air pressure causes the hand to move, making an error in the observation. This can be corrected, however, by comparing its readings with those of another barometer kept at a fixed place.

As in the case of thermometers, there are self-recording barometers, or *barographs*. In these, as in thermographs, a pen point pressed against a roll of paper on a cylinder, revolved by clockwork, gives a continuous record of changes in pressure.

3. Anemometers. — Wind *direction* is determined by the ordinary *weather vane*, and the *rate* at which the air is moving by the *anemometer* (Fig. 566). The latter instrument consists of four metal cups on crossbars, revolved by the wind striking the hollow side of the cups. Each revolution is communicated

to a cog-wheel, which causes a hand to move on a dial, recording the velocity.

Wind velocity is measured in miles per hour, and the dial is so graduated that the hand indicates the number of miles the wind has moved. An anemometer may be connected by electric wire to a self-recording apparatus.

A slight breeze has a velocity of from 1 to 10 miles per hour; a strong wind from 20 to 30 miles; a gale from 40 to 60 miles; and a tornado wind even as much as 200 miles per hour.

4. Measurement of Vapor. — There are several instruments for determining the humidity of the air. One of these is the *hair hygrometer*, which consists of a bundle of hair robbed of its oil. Such hair will absorb vapor, changing in length as the amount of absorbed vapor varies. It is because of this fact that the hair of many people becomes straight in damp weather. In the hair hygrometer a hand is moved over a graduated scale, in one direction if the humidity is high, in the other if it is low.

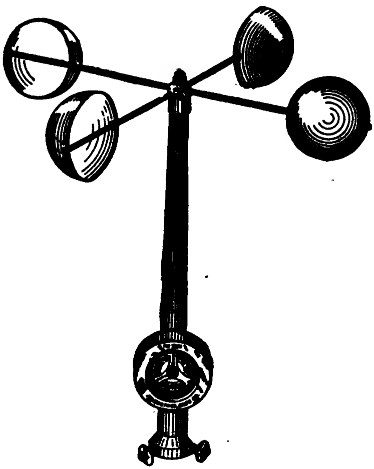

FIG. 566. — An anemometer.

Another instrument, the *sling psychrometer*, consists of two thermometers attached to a board, one having a piece of wet muslin around its bulb. Its use depends upon two facts: (1) That evaporation is more rapid in dry than in humid air; (2) that evaporation lowers the temperature.

Since evaporation is more rapid when the air is moving, the sling psychrometer is whirled around for a minute or two. If the air is saturated, there will be no evaporation from the wet muslin, and the two thermometers will, therefore, read the same; but if the air is dry, the wet bulb thermometer will register a perceptibly lower temperature. The United States Weather Bureau furnishes

tables from which the relative humidity can be calculated, when the difference in temperature between the dry and wet bulb thermometers has been determined.

Various instruments are used for determining the *rate of evaporation*, which varies from day to day and from place to place. An *evaporating pan* consists of a dish of water in which is placed a ruler graduated in inches and tenths of inches. By this, one can tell how much is evaporated from the water surface in a given time. Rain should be prevented from falling into the pan, but it should be freely open to the air. It should not be exposed to the sun, because warming increases evaporation. It is best to place it in the ground with the top level with the surface.

5. Rainfall Measurement. — Rainfall is recorded in number of inches and tenths of inches that falls on a given surface. Any cylinder, as a tomato can, could be used as a *rain gauge*, or measurer; but an ordinary rainfall is so slight that it would be difficult to measure it unless some provision were made for collecting the water in a smaller space than the surface on which it fell.

Any tinsmith can make a rain gauge, with two cylinders, one inside of the other, the inside cylinder having one tenth the diameter of the outside one (Fig. 561). A funnel fits over the outside cylinder, and a hole in it leads into the inside cylinder. The rain that falls on the funnel, whose diameter is just ten times that of the inner cylinder, collects in the bottom of the inner cylinder to a depth ten times that of the actual rainfall. Measuring this with a ruler, and dividing by ten, gives the actual rainfall, even though it is slight. There are also self-recording rain gauges.

Instruments are sometimes used for measuring snowfall; but usually this can be fairly well done by measuring its depth in some place where it is not drifted. The average snowfall is about ten times the amount that would have fallen as rain. In weather records it is customary to record snowfall in inches of rain. Place snow in a cylinder, filling it to a depth of a foot, and melt it to see how much water it produces. Do not pack the snow down.

6. An Instrument Shelter. — In order to get good results, meteorological instruments must be placed where they are not influenced by local conditions. For example, two thermometers, one in the shade, the other exposed to the sun, will give very different readings. A simple *instrument shelter*, made of inclined, overlapping slabs, far enough apart to let the air circulate freely, and yet near enough together to keep the sun out, is easily made. It should be placed either on open ground or on the roof.

The barometer may be kept in the schoolroom, the rain gauge on open ground away from a building, and the anemometer on the roof; but the other instruments are best kept in an instrument shelter.

SUGGESTIONS. — For purchase of meteorological instruments, see p. 438. As indicated above, it is possible to make several of the common instruments, especially the barometer, psychrometer, evaporating pan, and rain gauge. This might easily be done in the manual training department. With these instruments daily records may be kept, and laboratory work of value done, especially for comparison with the study of weather maps and storms. Daily and seasonal temperature curves may also be made. If this work is carried along with the study of the atmosphere, the teacher will find many opportunities for connecting observations with facts in the book. For example, observe the humidity of the air near the ground when dew is forming and when it is not. When frost is forming, take the temperature of the ground and of the air 10 feet above it to see if radiation cools the ground. After the barometer begins to fall, does it rain? What change in wind direction then takes place? In temperature, etc.?

SUGGESTED RECORD.

	JANUARY 1, 1903.			JANUARY 2, 1903.			JANUARY 3, 1903.		
	8 A.M.	1 P.M.	8 P.M.	8 A.M.	1 P.M.	8 P.M.	8 A.M.	1 P.M.	8 P.M.
Temperature	5°	10°	2°	−1°	20°	18°	17°	30°	31°
Barometer	30.0	30.0	30.1	30.1	30.0	29.9	29.8	29.7	29.6
Wind	West	West	Calm	Calm	S.W.	S.W.	South	S.E.	East
Wind Force	Moderate	Strong	Calm	Calm	Light	Breeze	Light	Strong	Gale
Sky	Clear	Cumulus	Clear	Clear	Clear	Cirrus	Cirrus	Cirro stratus	Stratus
Rainfall	0	0	0	0	0	0	0	.1 light snow	.3 heavy snow
Humidity	80	60	82	85	55	85	90	100	100

APPENDIX H. WEATHER MAPS.

THE U. S. Weather Bureau issues daily maps showing weather conditions throughout the country. By application these can doubtless be secured for the school, and, being placed in the schoolroom, will serve as a valuable basis for laboratory study.

The weather maps are based upon reports telegraphed from Weather Bureau Stations in all sections of the country; and the facts regarding temperature, rainfall, and wind are placed in a table at the bottom of the map. On the basis of these reports, predictions for the next day are made at a central office.

On the map, which is an outline map of United States, the direction of the wind is indicated by arrows. At the ends of some of the arrows is the letter R, meaning rain, or S, meaning snow. Arrows that terminate in blank circles ( ) mean clear weather; when crossed by a line ( ), partly cloudy; and when occupied by a cross ( ), cloudy. The centers of high and low pressure areas are indicated by the words *High* and *Low*. Dotted lines (*isothermal lines*) pass through places having equal temperatures, and continuous lines (*isobaric lines*) pass through places with equal air pressure. The barometric readings (29.8, 30.1, etc.) are all reduced to sea level; that is, made to read as they would if the station were at sea level.

Thus the weather maps, besides describing the weather conditions and predicting for the next day, contain a large amount of information concerning the weather of different sections. A study of the maps on several successive days will make their meaning plain, and will illustrate many points discussed in the book.

Sets of maps suitable for the work suggested below are easily obtained by keeping the maps for a year or two. Out of date sets may possibly be obtained from the Weather Bureau. Or the teacher could make large wall maps for class use, selecting typical sets, and sketching the weather conditions on a large outline map of United States.

SUGGESTIONS. — (1) Study a weather map to understand its meaning. Which isotherm passes nearest your home? What other places have the same temperature? What is the air pressure? What other places are on the same isobar? Is the weather at your home clear, cloudy, or rainy? What is the wind direction? How do these facts compare with your

own observations the previous day? Study the weather maps for the next two days. What differences are noticed? Do you find any explanation? (2) Select weather maps to illustrate a typical storm. Have each student make a copy of it on a blank map of United States. Have them tell in what parts the pressure is low, and where high. Shade between the isobars. Shade on the map the rainy or snowy sections. With another colored pencil, mark the cloudy areas. What is the direction of the winds in the different areas? What part of the storm area is warmest? What part coolest? What is the direction of the wind in each case? Can you find an explanation of any of the facts observed? (3) In the same way, study the weather maps for the next three days. Write a statement of the changes that have occurred. On an outline map draw the path followed by the storm center. Select some place on the map, and have the students describe the weather changes — pressure, temperature, wind, and rain — for the four days. (4) In the same way study a set of maps in which a typical high pressure area, or anticyclone, passes across the country. (5) On an outline map plot around the same central point the winds of three well-defined storms. Also three anticyclones. What about their direction? (6) Give to each student a map with a well-defined storm, and have him tell what he thinks the weather conditions were the day before, and what they were the next day. First remove the predictions from the map. After the predictions have been written down, show the actual maps. This practice may be continued until the class becomes fairly proficient in predictions. Toward the end of these exercises have the students sketch their predictions on outline maps; that is, upon the basis of their study of a map for a given day, let them make a weather map of the previous and succeeding days. Care should be taken to select well-defined storms that move regularly, otherwise the results may be poor. (7) Give out problems; many will be suggested by a study of a series of weather maps. For example, given a well-defined low at Chicago, temperature 34.5°: is it clear or rainy? Is the temperature probably higher or lower at Minneapolis? At Indianapolis? On a sketch map of United States indicate the area of probable snow. Of rain. What will the weather probably be next day at Chicago? At Cleveland? (8) Upon the basis of observations with instruments in the school make weather predictions. (9) Each day give the weather map to one of the students, and let him report the facts of barometer, temperature, position of highs and lows, etc.; or, better, sketch them on an outline map for the class to see. Then call for predictions from the class, and have them give their reasons. Then read the prediction on the map. Next day call for a statement of how nearly correct the prediction was.

APPENDIX I. MAPS.

Various methods are employed to represent the surface of the earth by maps. Among these are relief maps, hachure maps, and contour maps, all of much value in a study of physical geography.

1. Relief Maps or Models.—Ordinary maps are flat; and the usual political map makes little attempt to represent relief. Yet by shading, or by color, some are made to indicate the general distribution of highlands and lowlands. A far better means of representing a country is by relief map, or model, in which the surface is actually raised to represent irregularities of the land.

Owing to the small size of such maps, it is usually necessary to exaggerate the vertical, that is, make the scale of elevation, or vertical scale, different from the horizontal scale. Thus one inch vertically may represent 1000 feet, while in the horizontal scale an inch represents 10,000 or even 20,000 feet. To avoid wrong impressions from the use of such maps, care should be used to understand and make allowance for this exaggeration.

The great expense of making relief maps prevents their use in most school laboratories. Figures 22–26, 114, 460, 461, 464, 476, 477, and 485 are photographs of such models.

2. Hachure Maps.—The United States Coast Survey and the surveys of many European countries make use of *hachures* to represent irregularities of the surface of small sections. A hachure map is one in which the relief is brought out by shading, through the use of lines drawn more or less closely together, and all pointing in the direction of the slope (Fig. 562). Such a map is very graphic, and exceedingly useful in a study of the general form of the land. For some purposes its usefulness is lessened by the fact that, though it clearly brings out *differences* in elevation between adjoining regions, it does not tell the *actual* elevations.

3. Contour Maps. — The fact last mentioned has led other surveys, for example the U. S. Geological Survey, to adopt *contour lines*, or lines passing through places of equal elevation.

Imagine a rather irregular beach at low tide when there are no waves. The water marks a contour line, and extends up the depressions, or valleys, in the sand. This may be called the 0 contour; if the tide rises five feet, a new contour is marked five feet above the other. This might be called the five-foot contour.

In making contour maps, sea level is reckoned as 0, and each contour passes through all places on the map that are at the same level above sea; that is, places which the sea would touch if it rose that high. Every place through which the 100-foot contour passes is just 100 feet above sea level. On such maps, therefore, it is possible to tell the elevation of every place. Contour maps do not express relief so graphically as hachure maps, but, with a little study, one learns to quickly interpret from them the forms of the land. Plains have few contours, far apart; gorges have many, close together; rounded hills have contours of different shape from those on steep-sided hills, etc. Figures 78, 82, 121, 131, 137, 145, 192, and 193 are contour maps.

On the U. S. Geological Survey maps the horizontal scale is usually about one inch to the mile. The vertical scale, or *contour interval*, is usually 20 feet; that is, a contour is drawn for every 20 feet of elevation. Therefore, the vertical distance, or interval, between two contours is 20 feet. In sparsely settled or mountainous regions a contour interval of 100 feet is often chosen.

Suggestions. — (1) Find out if the U. S. Geological Survey (Washington, D. C.) has issued a contour map of your vicinity. If so, get a copy (cost 5 cents), mount it (p. 437), and carry it on your walks or bicycle rides. You will find it of great service. (2) Let the class have practice in making simple contour sketches; for example, have them make contours to show a round hill, a long hill, a hill steep on one end, two hills and a valley, a broad valley, a gorge, etc. Also draw simple contour sketches on the board (for example, a round hill), and have the class make cross sections of them; that is, sections to show the profile as if the hill were sliced through. Keep the class at this work until they understand how to do quickly what is given. (3) From some model select a section, and have the class sketch a contour map of it. (4) Obtain a series of contour maps, and have the class make cross sections along lines drawn on the map by the teacher. To make these sections, first draw a line on the paper equal in length to the line on the map. Then, for the vertical scale, draw, parallel to this, other lines $\frac{1}{16}$ inch apart.

Let the distance between two of these lines represent 20 feet. Then proceed to draw the profile. (5) After some practice in cross-sectioning, select a series of maps and assign to each student part or all of a map to define the topography in words. This may well be followed by other maps. (6) The teacher may, possibly, deem it worth while to have the class make a map of a small area. With a tape line, an aneroid barometer, a level, and a compass, a rough map may easily be made. (7) If the teacher would each year have a model made by the class, the school would soon accumulate a valuable equipment. It is not very difficult to make a model. For the first one start with a simple region — say the Marion, Iowa, sheet. Find the lowest contour on the sheet and transfer it to tracing paper, then to a thin cardboard sheet the size of the map. Then cut the cardboard along the line. Tack it to a board, or thick cardboard, the size of the map. Do the same for the next highest contour, and tack this to the first. Continue until there is a pile of cardboards, one for each contour. Divided among many, this is not a very difficult task. With molding wax, smooth the surface so that no cardboard edges appear. After one or two trials a very satisfactory model will be made. On more complex sheets it is not necessary to trace every contour. An interesting model may be made by starting with a large number of sheets of the same map and, instead of tracing the contours, cut the map itself, and paste sheet on sheet until each contour is represented. To cut the sheets with an even edge, lay the map on a sheet of glass or zinc and cut it with a sharp knife.

Reference Book. — GANNETT, *Manual of Topographic Methods*, Monograph XXIV, U. S. Geological Survey, Washington, D.C. 1893, $1.00.

Fig. 567. — A physical geography laboratory. Models are attached to the walls, and over by the window is a frame (on rollers) containing two models. A case for flat maps is in the foreground, and one for rolled maps on the left near the door. Brass rods, for hanging maps, are placed over the models; and, suspended from the ceiling, are others which may be lowered by means of pulleys.

FIG. 568.—Same laboratory as 567, from other end, with maps hung on the rods. Those on the ceiling rods, in middle of room, may be lowered. Large table, made by grouping small tables, in foreground. Students are seated around this for map work. It is possible to assemble around this table a large assortment of models, maps, and photographs, for use during a laboratory period.

APPENDIX J. LABORATORY EQUIPMENT.

1. Models. — *E. E. Howell* (612 17th St., N.W., Washington, D.C.) has a number of models of great value in laboratory work. He also offers for sale large photographs of these. Catalogue sent on application. *G. C. Curtis* (64 Crawford St., Boston, Mass.) has a set of three excellent geographical models (*glaciers*, *volcanoes*, and *seacoast*). The *Harvard Geographical Models*, a set of three, are sold by Ginn & Co., Boston, for $20 a set. These last two sets should be in every laboratory of physical geography. The *Jones model* of the earth is very valuable (cost $50, A. H. Andrews & Co., Chicago). For construction of models from topographic maps, see page 430.

2. Maps. — The *Kiepert* and the *Habenicht & Sydow* relief maps of continents and parts of Europe are the best maps of this nature. The various government bureaus (see below) will on application send catalogues of their maps, from which the teacher may select those desired. The following lists have been carefully prepared to secure representative maps of various phenomena, and they may serve as the nucleus of a map collection for laboratory use. For further suggestions, see pamphlet by DAVIS, KING, and COLLIE, *The Use of Governmental Maps in Schools* (Henry Holt & Co., New York, 1894, $0.30); also DAVIS, *Journal of Geology*, Vol. IV, 1896, p. 484. Foreign maps may be imported through G. E. Stechert (9 East 16th St., New York).

The entire United States coast is charted by the U. S. Coast Survey, and many parts of the country are mapped by the U. S. Geological Survey. All of New Jersey, Massachusetts, Connecticut, Rhode Island, and most of New York are now mapped, as well as portions of each of the other states. The Geological Survey topographic sheets may be ordered for $0.05 each, or at the rate of $0.02 a sheet if 100 or more are ordered. Money must be sent by money order *in advance*. The Geological Survey also issues special maps, for example a series of different scale maps of United States; also geological folios, — perhaps of your district.

Each school should have sets of the *United States Geological Survey Physiographic Folios*, especially the first two. They contain selected maps, with description, to illustrate physiographic types. Folios 1 and 2 cost $0.25 each; No. 3, $0.50.

3. Use of Topographic Maps. — The use made of topographic sheets will vary with the teacher, the time available, and the number and variety of sheets at hand. The following is the method adopted by one teacher, who has all the maps he needs, both American and foreign. After the students become familiar with the meaning and use of topographic maps (p. 429), a topic is chosen for a laboratory period, say glacial action, or one phase of it, and typical maps (combined sheets) illustrating the phenomena are hung about the room to be studied and interpreted, careful notes being taken. At the close of the period a review quiz is held by the teacher, with the object of correlating observations and bringing out points whose full significance may not have been apparent to the students. The lesson is definitely correlated with the text-book work, and generally covers a topic then being studied.

In addition to the wall maps, single sheets are placed in the hands of each student, each sheet clearly illustrating some one phase of the topic chosen. This illustration the student must discover by observation. The study proceeds somewhat as follows: (1) *Location:* (*a*) latitude; (*b*) longitude; (*c*) position on United States contour map; (*d*) physiographic relationships (*i.e.* on coastal plain, in Adirondacks, etc.). (2) *General physiography:* (*a*) highest elevation; (*b*) lowest section; (*c*) direction of rivers; (*d*) abundance or scarcity of tributaries; (*e*) humid or arid region; (*f*) form of valleys; (*g*) slopes; (*h*) nature of divides; (*i*) direction of roads; (*j*) influence of physiography on roads, railways, and settlement. (3) *Specific points* (for example, on Elmira, N.Y., sheet): (*a*) find morainic hills near Lower Pine Valley — the ice front stood there; (*b*) describe the valley south to Elmira and southwest to East Corning; (*c*) measure its width and compare with that occupied by the Chemung River west of Elmira; (*d*) what is a wash plain (see text-book)? (*e*) could this be a wash plain? If so, what change has it caused in the depth of the valley? Would it account for the broad, flat-bottomed valley followed by the railroad? Might it have raised the valley bottom so high that the Chemung could not follow its former course via Horseheads? This is what has happened.

The subject can be developed formally by mimeographing questions, or putting them on the blackboard; or, better, if the class is not too large, by giving general directions, then asking specific questions, either of the class as a whole or of individuals. Work done on individual sheets is included in the review at the end of the exercise.

By the above method, when plains are studied laboratory exercises may accompany the recitation work; the same with shore lines, lakes, mountains, etc. The student should not be allowed to be diverted by other phenomena than those directly bearing on the topic. The same

map may often be used in several periods to illustrate different phenomena. In this work the student is expected to look for comparisons and contrasts; for example, under "Plains," compare and contrast the Fargo, N.D., Kaibab, Ariz., and Palmyra, N.Y., sheets.

Another method used is to study a sheet to detect all phenomena represented; but this lacks many of the advantages of a study by topics. In the absence of a regular laboratory manual, it is necessary for teachers to develop their own methods, and this Appendix is merely a hint as to one direction in which this may be done. It calls for sacrifice of time and energy on the part of the teacher; but all who are willing to make this sacrifice will be abundantly repaid by the improved work and greater interest of the class. Even if formal laboratory work is not given, the maps are of great use as illustrations of the text.

4. One Hundred Selected Sheets, United States Geological Survey, Topographic Map. — *These maps should be purchased by the hundred* ($2 a hundred); and it is desirable to provide enough sets for each student in the laboratory to have a copy of each, or, at least, to provide one for every two students. They should be mounted (p. 437).

(1) *Glassboro, N.J.*; (2) *Leonardtown, Md.*; (3) *Pt. Lookout, Md.*; (4) *Fargo, N.D.*; (5) *Hamlin, N.Y.*; (6) *Marion, Iowa*; (7) *Wichita, Kan.*; (8) *Butler, Mo.*; (9) *Marshall, Ark.*; (10) *Lamar, Colo.*; (11) *Brownwood, Tex.*; (12) *Coleman, Tex.*; (13) *Higbee, Colo.*; (14) *Kaibab, Ariz.*; (15) *Watrous, N.M.*; (16) *Boise, Idaho*; (17) *Modoc Lava Bed, Cal.*; (18) *Elmira, N.Y.*; (19) *Kaaterskill, N.Y.*; (20) *Gaines, Pa.*; (21) *Briceville, Tenn.*; (22) *Scottsboro, Ala.*; (23) *Salyersville, Ky.*; (24) *Huntington, W. Va.*; (25) *Pikeville, Tenn.*; (26) *Bisuka, Idaho*; (27) *Great Falls, Mont.*; (28) *St. Paul, Minn.*; (29) *Palo Pinto, Tex.*; (30) *Delaware Water Gap, Pa.*; (31) *West Point, N.Y.*; (32) *Jefferson City, Mo.*; (33) *Junction City, Kan.*; (34) *Kearney, Neb.*; (35) *Lexington, Neb.*; (36) *Donaldsonville, La.*; (37) *Point a la Hache, La.*; (38) *Cohoes, N.Y.*; (39) *Springfield, Mass.*; (40) *Alturas, Cal.*; (41) *Pikes Peak, Colo.*; (42) *Telluride, Colo.*; (43) *Platte Canyon, Colo.*; (44) *Huerfano Park, Colo.*; (45) *Livingston, Mont.*; (46) *Mt. Washington, N.H.*; (47) *Becket, Mass.*; (48) *Monadnock, N.H.*; (49) *Hartford, Conn.*; (50) *Mt. Marcy, N.Y.*; (51) *Monterey, Va.*; (52) *Fort Payne, Ala.*; (53) *Estillville, Ky.*; (54) *Franklin, W. Va.*; (55) *Maynardville, Tenn.*; (56) *Hazleton, Pa.*; (57) *Lykens, Pa.*; (58) *Atlanta, Ga.*; (59) *Lassen Peak, Cal.*; (60) *Shasta, Cal.*; (61) *Mt. Taylor, N.M.*; (62) *Marysville, Cal.*; (63) *Ashland, Ore.*; (64) *Henry Mountains, Utah*; (65) *Sierraville, Cal.*; (66) *Disaster, Nev.*; (67) *Paradise, Nev.*; (68) *Granite Range, Nev.*; (69) *Tooele Valley, Utah*; (70) *Salt Lake, Utah*; (71) *Boothbay, Me.*; (72) *Coos Bay, Ore.*; (73) *Seattle,*

Wash.; (74) *San Francisco, Cal.*; (75) *New Haven, Conn.*; (76) *Brooklyn, N.Y.*; (77) *Charlestown, R.I.*; (78) *New London, Conn.*; (79) *Duluth, Minn.*; (80) *Pulaski, N.Y.*; (81) *Marthas Vineyard, Mass.*; (82) *Atlantic City, N.J.*; (83) *Barnegat, N.J.*; (84) *Sandy Hook, N.J.*; (85) *Boston Bay, Mass.*; (86) *Mt. Lyell, Cal.*; (87) *Minneapolis, Minn.*; (88) *Plymouth, Mass.*; (89) *Stonington, Conn.*; (90) *Baldwinsville, N.Y.*; (91) *Newcomb, N.Y.*; (92) *Elizabethtown, N.Y.*; (93) *Plattsburg, N.Y.*; (94) *Skaneateles, N.Y.*; (95) *Ovid, N.Y.*; (96) *Lacon, Ill.*; (97) *Ottawa, Ill.*; (98) *Watertown, Wis.*; (99) *Weedsport, N.Y.*; (100) *Oswego, N.Y.*

The following must be ordered as *Special Sheets*: (A) *Norfolk Special*, $0.10; (B) *New York City and Vicinity Special*, $0.25; (C) *Rochester Special*, $0.10; (D) *Niagara River and Vicinity Special*, $0.10; (E) *St. Louis and Vicinity Special*, $0.10; (F) *Crater Lake Special*, $0.05.

The following classified list calls attention to some of the principal features illustrated on the above maps. The teacher will find others.

Coastal Plain, 1–3, 82, 83, A; *Lake Plains (West)*, 59, 65–70; *Lake Plains (Lake Agassiz)*, 4; *Lake Plains (Ontario)*, 5, C, D; *Lava Plains (Plateaus, West)*, 16, 17, 26, 61; *Central Plains*, 6, 8, 32, 96, 97; *Great Plains (more or less dissected)*, 7, 10, 12, 27, 29, 33, 35; *Dissected Arid Plateau*, 13, 14, 15, 61; *Escarpments*, 14, D; *Mesas*, 11, 13, 14, 15, 61; *Buttes*, 12, 13, 26; *Desert*, 66–70; *Desert Sand Dunes*, 66, 67; *Dissected Moist Plateaus*, 9, 18, 23, 25, 94, 95; *Catskills*, 19; *Immature Drainage*, 1, 83, A; *Post-glacial Young Streams*, 28, 38, 94, 95, 96, C, D; *Young Valleys*, 9, 13, 26, 27, 49; *Waterfalls*, 27, C, D; *Canyons*, 13, 14, 16, 26; *Mountain Gorges*, 43, 45; *Water Gaps*, 30, 31, 51, 52, 57; *Mature Valleys*, 18–24, 38, 39, 47–58, 75, 94, 95; *Arid Land Drainage*, 13–16, 40, 65–70; *Alluvial Fans*, 45, 65; *River-made Plains*, 60, 62; *Braided Course*, 34, 35, 66; *Floodplains*, 8, 9, 32, 34, 35, 87, 96, 97, E; *Bluffs*, 32, 35, E; *Levee*, 36; *Crevasse*, 36; *Meanders*, 8, 32, 33, 52, 53, 55, E; *Intrenched Meanders*, 23, 29; *Delta*, 93; *Terraces*, 38, 39, 49, 96; *Erie Canal*, 99; *Irrigation*, 10, 70; *Basin Ranges*, 40; *Coast Ranges*, 60, 72, 74; *Sierra Nevada*, 65; *Rocky Mountains*, 41–45; *Appalachians*, 21, 25, 30, 51–57; *Adirondacks*, 50, 91, 92; *New England Mountains*, 46–49, 75, 77; *Piedmont*, 58; *Young Mountains*, 40–45, 60, 65, 72, 74; *Mountains (early maturity)*, 46; *Mature Mountains*, 30, 31, 39, 47, 57, 71, 75, 77, 78, 89, 91–93; *Mountain Ridges*, 51–57; *Old Mountains*, 58, 85; *Peneplain*, 58; *Monadnocks*, 48, 58; *Volcanoes*, 59–62, F; *Laccolites*, 64; *Trap Ridges*, 39, 75; *Palisades*, B; *Glaciers*, 60; *Cirques*, 86; *Moraines*, 76, 77, 81, 87–89; *Wash Plains*, 18, 76, 77, 81; *Moraine Kettles*, 88; *Kames (Pinnacle Hills)*, C; *Drumlins*, 49, 85, 90, 98–100; *Glacial Lake Overflow Channels*, 90, 96, 97, 99; *Lake on Coastal Plain*, A; *Delta Lakes*, 37; *Ox-bow Lakes*, 8, 33, E; *Volcanic Lakes*, 59; *Crater Lakes*,

59, 63, F; *Glacial Lakes and Swamps*, 31, 45, 47, 48, 50, 77, 78, 85–94, 98–100; *Lake Champlain*, 93; *Finger Lakes*, 94, 95; *Coastal Plain Swamps*, 1, A; *River Swamps*, 1, 62, 87, 96, A; *Delta Swamps*, 36, 37; *Lake Swamps*, 80, 93, 100, C; *Alkali Flats and Playas*, 65, 66, 68; *Drowned Coastal Plain*, 2, 3, 83, 84, A; *Drowned Coast*, 71–78, 81, 85, 89, B; *Drowned Lake Coast*, 79, 80, 93, 100, C; *Harbors*, 73–75, 78, 79, A, B; *Wave-cut Cliffs*, 84, 100; *Wave-cut Islands*, 85; *Beaches*, 72; *Tied Islands*, 85; *Bars, shutting in Bays*, 77, 79–81, 85, 100, C; *Sand Bars*, 76, 78, 81, 88, 89; *Hooks*, 84; *Sand Dunes*, 72, 83, 84; *Offshore Bars, inclosing Lagoons*, 82–84, A; *Salt Marshes*, 74–76, 78, 82, 85, 89, A, B.

5. Thirty-five Grouped Sheets. — *The following groups of sheets are selected for mounting to make large maps* (see directions below). Each group illustrates well at least one phenomenon, and a number illustrate several. In addition, they all contain many important details worthy of study. It would also be desirable to secure and mount in a large map all the sheets in the vicinity of the home region. Nearly all of these sheets could be used singly if mounting in groups seems too difficult.

1. Colorado River and Vicinity — illustrating plateaus, mesas, buttes, canyons, volcanoes, arid drainage, the following sheets: (*Pioche, St. George, Kanab, Escalante, Henry Mountains*, **Utah**, *Marsh Pass, Echo Cliffs, Kaibab, Mt. Trumbull, St. Thomas, Camp Mohave, Diamond Creek, Chino, San Francisco Mt., Tusayan*, **Ariz.**). 2. Overburdened Platte River — also Great Plains (*Kearney, Wood River, Grand Island*, **Neb.**). 3. Same — (*Minden, Kenesaw*, **Neb.**). 4. Connecticut Valley — bordering upland, lowland, trap ridges, terraces, ox-bow lake (*Greenfield, Warwick, Northampton, Belchertown, Springfield, Palmer*, **Mass.**). 5. River Floodplain and Meanders — also Great Plains (*Kansas City, Oskaloosa, Olathe, Lawrence*, **Kan.**). 6. Mississippi Delta (*West Delta, East Delta*, **La.**). 7. Mississippi Delta and Floodplain — also location of New Orleans (*Bonnet Carre, Spanish Fort, Chef Menteur, Rigolets, Toulme, Bodreau, Shell Beach, St. Bernard, New Orleans, Hahnville, La Fortuna, Deine, Point a la Hache, Barataria, Cut Off, Forts, Quarantine, Ft. Livingston, Creole, Lake Felicity*, **La.**). 8. Alluvial Fans — arid region (*Pomona, Cucamonga, San Bernardino*, **Cal.**). 9. Coastal Plain — also shore lines, bars, marsh, etc. (*Bordentown, Cassville, Asbury Park, Pemberton, Whiting, Barnegat*, **N.J.**). 10. Coastal Plain — drowned, swampy (*Prince Frederick, Brandywine, Wicomico, Leonardtown*, **Md.**). 11. Coastal Plain — young drainage, lakes, and swamps (*Williston, Citra, Dunnellon, Ocala Isala, Aporka, Pana Soffkee*, **Fla.**). 12. Lake Plain — bed of Lake Agassiz (*Fargo, Casselton*, **N.D.**). 13. Great Plains (*Wichita, Cheney, Kingman, Wellington, Caldwell, Anthony*, **Kan.**). 14. Maturely Dissected Plateau (*Salyersville, Prestonsburg, Hazard,*

Whitesburg, **Ky**.). 15. SAME (*Huntington, Charleston, Kanawha Falls, Warfield, Oceana, Raleigh*, **W. Va.**). 16. MATURE MOUNTAINS AND PLATEAU (*Chattanooga, Sewanee, Ringgols, Stevenson*, **Tenn.**). 17. DISSECTED ARID LAND PLATEAU — canyons, mesas, buttes, etc. (*Higbee, Timpas, Apishapa, Mt. Carrizo, Mesa de Maya, El Moro*, **Colo.**). 18. MESAS, BUTTES, VOLCANOES, ARID DRAINAGE (*Wingate, Mt. Taylor*, **N.M.**). 19. APPALACHIAN RIDGES — Susquehanna, water gaps, broad valleys, etc. (*Sunbury, Shamokin, Millersburg, Lykens, Harrisburg, Hummelstown*, **Pa.**). 20. SOUTHERN APPALACHIANS (*Greeneville, Roan Mt., Ashville, Mt. Mitchell*, **N.C.**). 21. SOUTHERN APPALACHIANS (*Staunton, Monterey, Huntersville, Lexington, Natural Bridge, Lewisburg*, **Va., W. Va.**). 22. MOUNTAIN RIDGES —river meanders, Shenandoah valley (*Harpers Ferry, Winchester, Romney, Warrenton, Luray, Woodstock*, **Va.**). 23. NEW ENGLAND MOUNTAINS — even-topped upland, Monadnock (*Peterboro, Monadnock, Keene*, **N.H.**, *Fitchburg, Winchendon, Warwick*, **Mass.**). 24. ADIRONDACKS — part of Lake Champlain, glacial lakes (*Lake Placid, Ausable, Willsboro, Mt. Marcy, Elizabethtown, Port Henry, Schroon Lake, Paradox Lake, Ticonderoga*, **N.Y.**). 25. APPALACHIANS AND VIRGINIA PIEDMONT (*Goochland, Palmyra, Buckingham, Amelia, Farmville, Appomattox*, **Va.**). 26. PIEDMONT AND COASTAL PLAIN — location of Philadelphia (*Germantown, Norristown, Chester, Philadelphia*, **Pa.**). 27. DRUMLINS — glacial lakes, cities on river with rapids due to glacial action, also beaches and salt marshes (*Haverhill, Newburyport, Lawrence, Salem*, **Mass.**). 28. FINGER LAKES — mature plateau, post-glacial gorges, lake deltas (*Geneva, Auburn, Skaneateles, Ovid, Genoa, Moravia, Watkins, Ithaca, Dryden*, **N.Y.**). 29. DRUMLINS — drainage interfered with by drift, overflow channels, lake shores (*Oswego, Sodus Bay, Pultneyville, Weedsport, Clyde, Palmyra, Auburn, Geneva, Phelps*, **N.Y.**). 30. DRUMLINS — glacial lakes and swamps (*Madison, Sun Prairie, Waterloo, Watertown, Evansville, Stoughton, Koshkonong, Whitewater*, **Wis.**). 31. DROWNED COAST (*Gardiner, Wiscasset, Boothbay, Bath*, **Me.**). 32. SAME (*Boothbay, Bath, Freeport, Gray, Small Point, Casco Bay, Portland*, **Me.**). 33. BAYS, — bars, wave-cut cliffs, moraine, wash plain (*Marthas Vineyard, Gay Head*, **Mass.**). 34. CAPE COD — bars, wave-cut cliffs, sand dunes, moraine, morainic lakes (*Provincetown, Wellfleet, Chatham, Yarmouth, Barnstable*, **Mass.**). 35. YELLOWSTONE PARK (*Gallatin, Canyon, Lake, Shoshone*, **Wy.**).

6. Thirty Selected Sheets, United States Coast Survey, illustrating Typical Coast Lines. — (Washington, D.C. $0.50 each; catalogue free; order by number.) 6 (*General Chart, coast of Maine and Massachusetts*); 103, 104, 105, 106 (*Maine coast, more detailed*); 108 (*Coast from southern Maine to Cape Ann*); 109 (*Boston Bay*); 8 (*Approaches to New York, Gay Head to Cape Henlopen*); 113 (*Narragansett Bay*); 52 (*Montauk*

Point to New York, with Long Island Sound); 119 (*Southern shore of Long Island*); 121, 122, 123 (*New Jersey coast, Sandy Hook to Cape May*); 376 (*Delaware and Chesapeake bays*); 11 (*Cape Hatteras to Cape Romain*); 142 (*Cape Hatteras*); 147 (*Cape Lookout*); 15 (*Straits of Florida, Coral Reefs*); 170 (*Key West and Vicinity, Coral Reefs*); 1007 (*General Chart, Gulf of Mexico*); 188 (*Mobile Bay*); 19 (*Mississippi Delta and vicinity*); 194 (*Mississippi Delta*); 21 (*Galveston to the Rio Grande*); 212 (*Bar from Rio Grande northward*); 5400, 5500 (*California coast*); 3089, 8100 (*Drowned Alaskan coast*).

7. River and Lake Maps. — *The Mississippi River Commission* (*St. Louis*), and the *Missouri River Commission* (*St. Louis*) issue charts of these rivers, of which the following are especially useful. *Map of Alluvial Valley of Mississippi, 8 sheets* ($1 per set); *Upper Mississippi, 4 sheets* ($0.70 per set); *Mississippi, Charts* 8, 22, 35, 36, 38, 39, 52 of the map on scale of 1:20,000, showing meanders, oxbows, etc. ($0.26 per sheet). If the school is located on the river, the sheets of that vicinity should be secured.

Charts of the Great Lakes (*United States Engineer's Office, Detroit, Mich.*) illustrate many shore-line phenomena. *Nos.* 1, 5, 6; also *Lake Ontario, Niagara River, Lake Erie,* and *Lake St. Clair* are especially valuable. If the school is on the lakes, much use should be made of the lake charts, especially those near by.

8. Mounting Maps. — It is real economy to have all maps backed with cloth. This will be done by many bookbinders, or it can be done in the school, using a thin, bleached, white cotton cloth of ordinary width for single sheets; extra width for grouped sheets. Use ordinary flour paste, which costs very little if purchased from a paper hanger. For successful map mounting have a smooth surface (a large drawing board or table top) on which to tack the cloth. Stretch the cloth and tack it firmly on all sides, then thoroughly wet it. Apply paste to the back of the map and allow it to lie until thoroughly limp, then put it on the cloth, which must not be too wet. Carefully press the map to the cloth with a piece of clean cloth or a photographic roller. Leave until thoroughly dry (at least 24 hours).

Combined sheets must first be trimmed, leaving on alternate sheets a margin of ½ inch for adjoining sheets to overlap. For trimming, to secure an even cut, place the map on a sheet of zinc (tacked to a board), and, with a sharp knife, cut along a metal straightedge placed on the map. If a map is not complete, blank spaces may be filled with white paper.

Large maps should be rolled, and a wood turner will supply rollers at small cost; also strips for the top of the map. Curtain rings may be screwed into the wooden strip for hanging the map, which, for class use, may be hung to brass rods (⅜ inch in diameter) along the sides of the

room. A curtain hanger will make hooks to hang over the rods. If single sheets are also hung, Dennison gummed-cloth suspension rings may be used.

Single sheets are best kept in a case of shallow drawers, using care not to put too many in a drawer, for they are then difficult to handle. Rolled maps are best preserved when kept in a case with shallow partitions, allowing the rolled map to lie horizontally. A cabinet-maker will build a combined case for rolled and flat maps.

9. Minerals and Rocks. — *E. E. Howell*, 612 17th St., N.W., Washington, and *Ward's Natural Science Establishment*, Rochester, N.Y., offer cheap sets of minerals and rocks suitable for laboratory use in connection with Tarr's Geology or Physical Geography. *G. B. Frazer*, West Medford, Mass., is another reliable dealer.

10. Meteorological Maps, etc. — Application should be made to *have the weather map sent regularly to the school*; and duplicates of out of date maps may possibly be secured on application. Meteorological instruments (see p. 420) may be purchased of *J. P. Friez*, Baltimore, Md., or *H. J. Green*, Brooklyn, N.Y.

11. Lantern Slides. — Various firms now supply lanterns for schools, the most satisfactory being electric lanterns. A set of lantern slides, selected by Prof. W. M. Davis, is sold by *E. E. Howell* (address above); *T. H. McAllister* (49 Nassau St., New York) has a series of geographical slides, and *H. W. Fairbanks* (Berkeley, Cal.) has a set of western slides for sale. *John Troy* (Ithaca, N.Y.) will make a limited number of slides from Cornell University negatives at $0.25 each. He sends a blue-print catalogue on application.

APPENDIX K. FIELD WORK.

THE value of field work is such that every course in physical geography ought to be accompanied by at least some. No laboratory or text-book work can take the place of well-conducted field work; it is worth undertaking even if Saturday is the only time available for it. But a progressive school should provide regular periods for out-of-door work.

Directions for field work of sufficient explicitness to be useful as a guide cannot be given without taking up far more space than is available in this book. What kind of work to give is a question which can be settled only by local conditions; therefore the teacher must develop his own outline. There is no region without some good physiographic phenomena within easy reach.

Properly to make use of these field opportunities demands personal knowledge of methods on the part of the teacher. There are, of course, many teachers of physical geography who have not had the training necessary for this work; for even the universities have been giving regularly organized field courses only in the past few years. Most summer schools in large universities offer instruction in this direction, and any teacher who desires to give field work, but lacks the necessary training, can secure it easily and at slight expense. Knowing how field work is conducted in one region, any real teacher can adapt the same methods to his own needs.

It is by the introduction of laboratory work, indoors and out, that physical geography is gaining for itself a rank which is placing it on a par with other science courses in the secondary school curriculum. Ten years ago scarcely a secondary school in the country, and very few normal schools and universities, gave organized laboratory and field work in physical geography. Now many of the better secondary schools provide for it and have specially equipped laboratories. The normal school or university

course that does not include such work is now considered weak and unsatisfactory. If the next ten years witnesses an advance equal to that of the last ten, the same will be true of physical geography in the secondary schools. A course in chemistry and physics that is solely a text-book course is now considered ridiculous; the same should be true of physical geography. The fact that it is liable to be so considered within ten years should spur on every teacher of the subject to the effort to prepare himself for the work and provide for it. The task is not a great one, and the reward is well worth the effort.

The following are some of the phenomena that are liable to be found within easy reach of a school. (1) *Illustrations of weathering:* cliffs, ledges, bowlders, old stone or brick buildings. (2) *Nature of country rock:* in river valleys, railway cuts, quarries. In such places stratification, joint planes, folding and faulting, and fossils may possibly be found. (3) *The soil:* for characteristics and depth, look in cuts, as in (2). Is it a soil of rock decay or transported? If the former, study its origin in the cut. If the latter, how transported? (4) *River transportation:* road gutters, plowed fields, small wet-weather streams, — nature of work, load carried, disposition of load, result of removal. Fine examples of young stream valleys, alluvial fans, deltas, and waterfalls (over pebbles) are very often found in a road, field, or railway cut. (5) *River work and valley formation:* source of water; variation in volume; sediment load; variation; source of sediment; temporary disposal of it, — on stream bed, in bars, in floodplains, etc.; place of final deposit of sediment; effect of removal of sediment on valley form. The entire subject of river work and life history of valleys may be built up around one or two field excursions to a near-by stream. It is not necessary to have grand waterfalls or broad floodplains. A meadow brook has its full lesson. (6) *Shore lines:* a lake shore or the sea shore; even a river bank or the shore of a pond may serve. What are the waves doing? What work have they accomplished? Why are the pebbles round? Where has the ground-off material gone? What is the source of the pebbles or sand? Which way are they moving? Are there bars, wave-cut cliffs, small stream deltas, shore swamps? Perhaps there are all, possibly only one; in the latter case study that, even though it may seem very insignificant. (7) *Glacial phenomena:* striæ; till banks, — in railway or other cuts; nature of material; scratched stones, etc. Are the pebbles or bowlders foreign, *i.e.* unlike the country rock? Is the till unstratified? Why? Find cuts of stratified drift — evidence of water action. There may be moraines, kames, eskers, or drumlins.

Besides these there may be plains, or mountains, or plateaus, or volcanic phenomena. If so, so much the better; but profitable field work does not necessarily demand grand features. It will be well to have most of the excursions devoted to details and the study of principles; hence a seemingly small illustration may be of the very highest value. At the same time, the field work should not entirely ignore the broad, general features. A very profitable excursion may be conducted in a high tower, or on a high hill overlooking the surrounding country.

Field excursions should be made for the purpose of showing the relationship between physiographic phenomena and human interests. They may often be combined with the other excursion suggested above. For example, an excursion might well consider the reason for the location and the nature of work in a quarry; the location and the difficulties in the way of laying a railway, *i.e.* the cuts, tunnels, etc., necessary; the differences in the soil and their relation to plant life, and especially to crops; the location of mills, etc. Here again the broad control of physiographic conditions should not be overlooked. By all means, the field work should show clearly the significance of the location and development of the home town and its industries.

APPENDIX L. REFERENCE BOOKS.

THE reference books listed at the end of each chapter deal in part, if not entirely, with the topic treated in that chapter. There are a number of general books, some of which are included in those lists, which should be in every physical geography laboratory. Among these are most of the following: —

MILL, *International Geography*, Appleton & Co., N.Y., 1902, $3.50; HUXLEY, *Physiography*, Macmillan Co., N.Y., 1891, $1.80; GEIKIE, *Scenery of Scotland*, Macmillan Co., N.Y., 1901, $3.25; TARR, *Physical Geography of New York State*, Macmillan Co., N.Y., 1902, $3.50; LUBBOCK (Lord Avebury), *Scenery of England*, Macmillan Co., N.Y., 1902, $2.50; *National Geographic Monographs, Physiography of the United States*, American Book Co., N.Y., 1895, $2.50; SHALER, *Outline of the Earth's History*, Appleton & Co., N.Y., 1898, $1.75; SHALER, *Aspects of the Earth*, Scribner's Sons, N.Y., 1890, $2.50; GEIKIE, *Fragments of Earth Lore*, John Bartholomew, Edinburgh, 1893, 12*s.* 6*d.*; BONNEY, *Story of Our Planet*, Cassell, London, 1898, 7*s.* 6*d.*; GEIKIE, *Earth Sculpture*, Putnam's Sons, N.Y., 1898, $2.00; MARR, *The Scientific Study of Scenery*, Methuen & Co., London, 1900, 6*s.*; SALISBURY, *Physical Geography of New Jersey*, Vol. IV, Final Report, New Jersey Geological Survey, Trenton, 1902; DRYER, *Studies in Indiana Geography*, Inland Printing Co., Terre Haute, Ind., 1897, $1.25; POWELL, *Geology of the Uintah Mountains*, Department of the Interior, Washington, 1876 (out of print); GILBERT, *Geology of the Henry Mountains*, Department of the Interior, Washington, 1877 (out of print).

The following are leading magazines of geography, at least one of which it is desirable to have in the school: *Journal of Geography*, Chicago, Ill., $1.50; *National Geographic Magazine*, Washington, D.C., $2.50; *Bulletin of the American Geographical Society*, New York, $4.00; *Geographical Journal*, London, $6.00; *Scottish Geographical Magazine*, Edinburgh, $5.00.

The United States Geological Survey publishes Bulletins, Annual Reports, Monographs, Folios, and Irrigation Papers, many of which contain valuable physiographic material, possibly relating to your own region.

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